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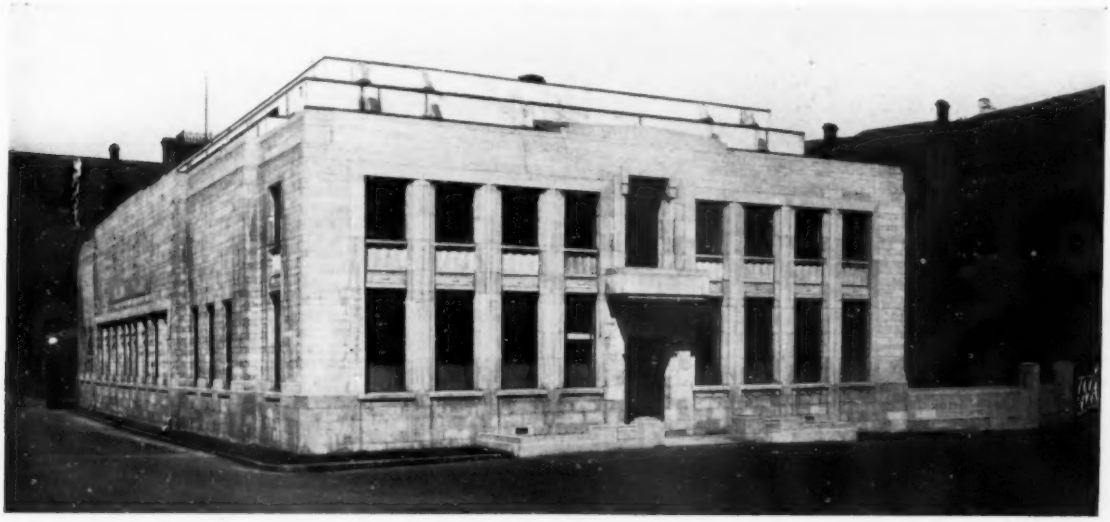
Works Research Service Scheme

Important New Laboratories at Stocksbridge

To-day we are realising that the great march of industrial progress depends essentially on research; not only routine research, which is usually associated with important producing units, but fundamental research, and the addition of the Central Research Department, recently opened by Lord Rutherford, Chairman of the Advisory Committee of the Department of Scientific and Industrial Research, to the group of services in the organisation of The United Steel Companies Limited should play an important part in assisting this progress.

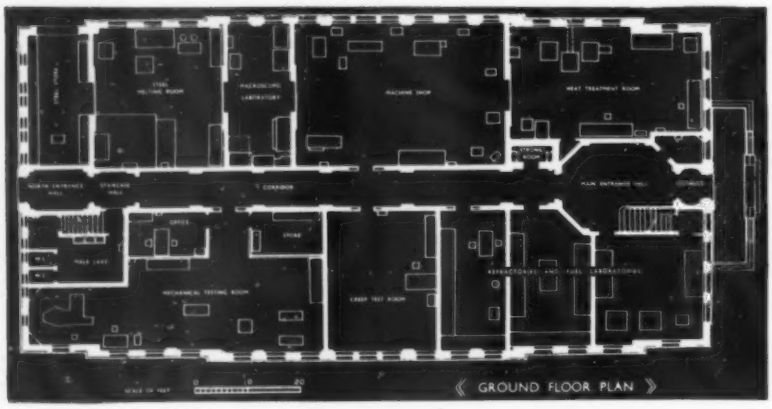
THE progress of engineering primarily depends upon the production of more reliable materials, and new materials, to meet conditions that exhaust the usefulness of existing materials, and it is only by persistent research that the demands of progress can be met. It is now fully recognised that in executing its functions of dealing with fundamental problems, the prime concern of a research department is the observation, investigation and development of scientific advancement with a view to its industrial application. The problems concern not only materials, but all ancillary processes employed in the production of these materials. In this work valuable aid is rendered by the various research associations, assisted by the Department of Scientific and Industrial Research; extremely valuable work is also done in the laboratories of the National Physical Laboratory, Woolwich Arsenal, the research laboratories connected with the Admiralty and Air Ministry, and also the research laboratories in various Universities.

These laboratories and associations fill an important place in the industry of the country, and their functions are clearly defined. It is, however, obvious in the natural order of things that large companies, particularly of such magnitude as The United Steel Companies Limited, should prefer that certain types of development research should be carried out under their own personal control, and in contact with their own particular production activities. In other words, excellent as they are, research facilities of an official character do not fill the complete requirements of a progressive industrial organisation anxious to perfect its methods of production and continually progressing in the production of better materials and new types of products. It is for this reason that The United Steel Companies Limited, which is a very important group of iron, steel, coal and coke producing units, with its own sources of supply for raw materials, iron ore, limestone and so forth, have built, equipped and staffed a Central Research Department. In order to indicate the position of this new central department in this group, it will be of interest to outline briefly the whole research organisation.



The New Central Research Department.

For many years works research laboratories have been established in all the important producing units of the group. These have certain well-defined functions, which embrace continuous contact with production for the purpose of investigating wastage and studying processes along with the production staff, in order to improve the technique of manufacture and manipulation; a staff of men with scientific training essential in carrying out the development of new processes, and the putting to work of new plant; a record of standard data of a technical character relating to all phases of production; the



Section showing a plan of the ground floor.

chemical analysis of raw material of all kinds, pass-test work in connection with furnace plant, and the analysis of resulting steel; advising both the sales departments and the production departments concerning enquiries for material of a special character; keeping in touch with customers' specific requirements, and advising customers in their particular problems; and the control and use of scientific instruments in the works, and in many cases to carry out a certain amount of construction of works apparatus and instruments.

Apart from the work of a more or less routine character, which has already been referred to, a large proportion of the inventions, discoveries, and improvements arise from a works demand, or by force of circumstances in connection with daily production. It is desirable, therefore, that this Works Research service shall be maintained, and developed, because it is clear that such a service must be located in the producing works. That such a scheme does not lead to overlapping in certain directions, where more than one works may be engaged in the investigation of the same type of problem, or in the testing of the same type of new product, is due to the system on which the whole scheme of research is organised. It is controlled by a Research Directing Committee, which meets at regular intervals and at each works in turn. This Committee actually operates through a series of sub-committees, the personnel of which is composed of the men most directly interested in a particular group of problems.

Those who have had experience know only too well how, with the best will in the world, it is difficult in the face of the daily pressure of a routine business, to carry out long-range research, or the investigation of intricate problems involving special apparatus and specially trained men. Yet a business of the magnitude of The United Steel Companies Limited should undertake research work of a character beyond that normally possible in a works research department, and a central research department becomes a necessity.

It is of interest to summarise briefly the functions of this new Central Research Department; these are: to plan and execute researches into new steels and new products of all kinds. To carry out more thorough investigations into the materials used than is normally possible in works research laboratories, with special reference to the development of new refractory materials. To undertake investigations of a special character of common interest to the whole of the works and to the industry generally. These may be typified by work on the creep strength of metals on the one hand, and intricate and improved methods of chemical analysis on the other. Incidentally, the company has for a considerable time concentrated on the standardisation of the methods of analysis and the production of standard steels for its own use, and this work is being continued in collaboration with the works research laboratories. The Central Research Department undertakes a precis service of important technical literature in the most commonly used languages and co-ordinates data for publicity purposes. It also works in close co-operation with the Chief Fuel Engineer, the Chief Efficiency Engineer and Chief Purchasing Agent in matters where technical data of a metallurgical character are required.

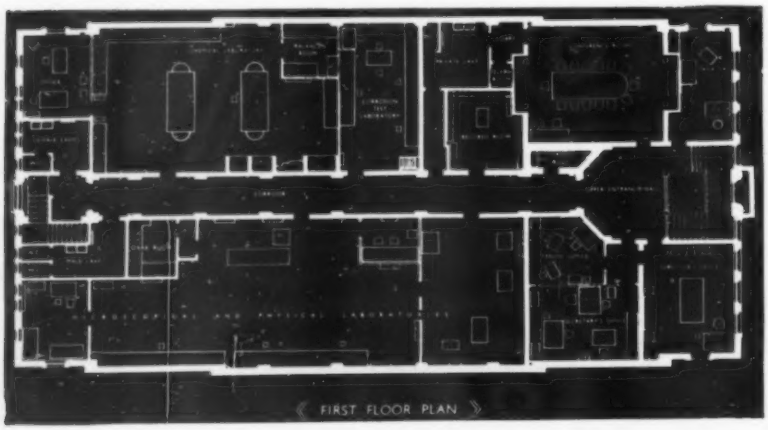
The staff of the laboratory is organised under a Manager into five groups, namely, Chemical, Physical, Metallurgical, Refractory and Literary services. Each of these groups is in charge of a highly trained university graduate, with a suitable staff specially selected for the type of work which it is called upon to carry out.

The New Department.

Constructed on very modern lines, this Central Research Department is a two-storey building designed to promote the atmosphere conducive to efficient working. Each floor is conveniently sectionalised to provide suitable accommodation for the various types of laboratories, and although it is not possible to discuss these in detail here, some of the rooms are of such interest that a brief reference to them is warranted.

The steel making room, for instance, is noteworthy. A special feature is the provision of two high-frequency furnaces, of one pound and eighteen pounds capacity respectively. These are interchangeable and work from the same 35 k.v.a. unit controlled by a carbon electrode-mercury spark-gap operating in an atmosphere of hydrogen. The large furnace is used mainly for producing experimental ingots, the standard size being 12 in. long by 2½ in. square, tapering down to 2 in. square. This furnace, melting at 15 to 20 kilowatts and a frequency of 20,000 cycles, is capable of producing 18 lb. ingots from a cold charge every 45 minutes. The actual lining consists of a crucible of suitable material (acid or basic) backed by a thin layer of rammed zirconia with an annular liner of fused silica immediately adjacent to the coil. The small furnace has a rammed lining and is capable of melting 1 lb. of steel from cold in

Section showing plan of the first floor.



about twenty minutes at 7 to 12 kilowatts, and a frequency of 30,000 to 40,000 cycles.

The equipment in the steel-melting room is typical of a miniature high-frequency melting shop, consisting of gas-fired furnaces for preheating feeder-heads, alloy stores, casting pit and stripping plate, and the general cleanliness is that associated with high-frequency melting practice.

All forging, rolling and working of experimental steels is carried out in the works under the direct supervision of the research laboratory staff.

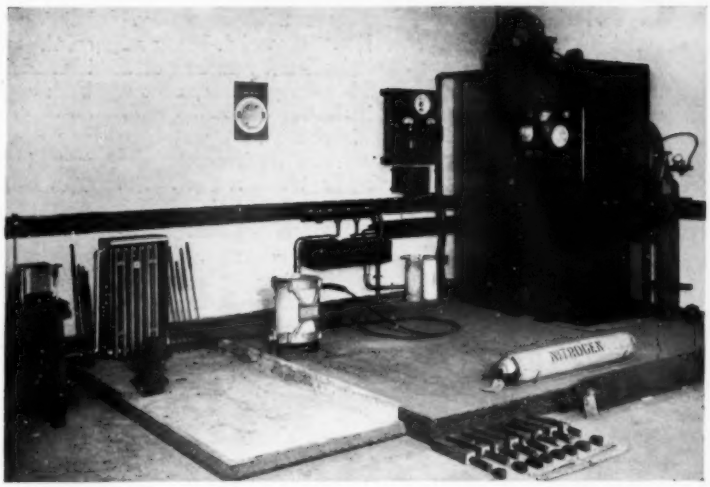
A special laboratory is allocated for microscopic examination which is carried out to reveal the soundness segregation and structure of full-sized sections of ingots, forgings, etc., and is an important application of research to steel manufacture with the object of producing sounder and homogeneous ingots. Ingot sections for examination are received in the machined condition and require polishing; this is carried out by means of a small portable electric sander which serves excellently for this work. After sulphur-printing, the ingots are etched while in position, on a part of the laboratory floor specially built for this purpose, where a copious supply of water and the necessary acid are conducted away. Photographing of the etched ingot is conveniently carried out with two projector lamps, the light from which may be concentrated or spread over large areas. Sections are deep-etched in a fume cupboard fitted in this laboratory.

The Department is fitted with its own machine shop, which is equipped with a milling machine, lathes, grinding machine, tool grinder, drilling machine, finishing machine, and hacksaw, each machine having an independent motor drive. These machines are of the latest type, capable of turning out work of the highest precision in the minimum of time.

In close proximity to the machine shop is the heat-treatment room, in which supervision of heat-treatment is reduced to a minimum by having furnaces with automatic temperature control. For temperatures up to 1,000° C. two G.E.C. furnaces are provided, one of which is fitted with recording apparatus. In addition there is a gas furnace capable of developing a temperature of 1,200° C. and an electric furnace with Silit rod heating elements having a maximum working temperature of 1,350° C. Ample provision is made for carrying out tests on small samples, and for special tests of long duration in suitable thermostatically controlled resistance wound furnaces, constructed in the laboratory.

Both rare metal and base metal thermocouples are used in temperature measurement, and for high temperatures the disappearing filament type of pyrometer has been adopted. The equipment includes a water-cooled oil bosh, which has been fixed in a convenient position relative to the furnaces, while there is also a movable water tank.

A feature of the Mechanical Testing Room is the special prismatic glass used for the windows to ensure well diffused natural lighting. Standard equipment for the testing of mechanical properties is installed in this room, comprising—two Wohler fatigue testing machines of the rotating bar single-point loading type; one Brinell hardness machine (Avery); one Vickers pyramid hardness testing machine; one Izod impact testing machine, and a 50-ton "Buckton" Universal compound lever testing machine. The latter machine is capable of carrying out tests in tension, deflection or compression, and is fitted with an automatic recording apparatus, further particulars of which are given elsewhere in this issue.



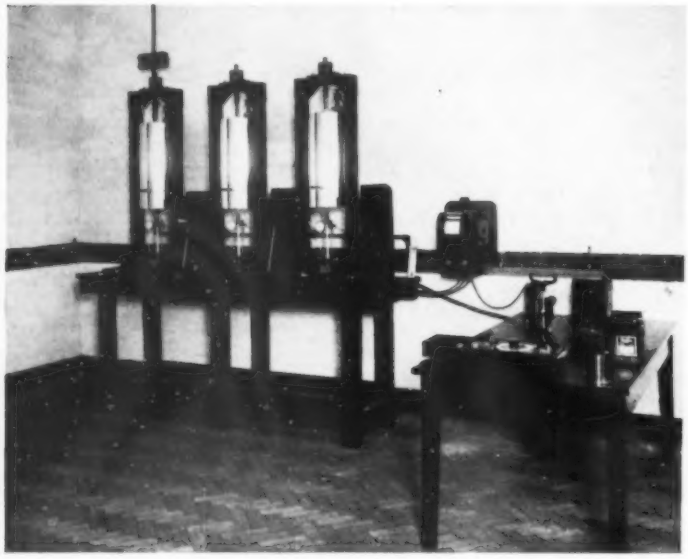
High-frequency electric steel melting plant.

In recent years, advances in engineering practice, particularly with regard to the employment of steels at elevated temperatures, have forced the metallurgist to devise new test procedures in an endeavour to obtain a complete knowledge of the behaviour of metals at high temperatures, and to supply satisfactory steels at an economic price. The tensile test as normally carried out, when performed at high temperatures, is no measure of the ultimate load-carrying ability of material, due to continuous deformation of "creep" taking place at a rate depending on the imposed stress. The test employed to determine strength at elevated temperatures, known as a "creep test," usually takes the form of determining for a selected temperature, the relationship between the applied stress and the rate of creep. Tests of this nature usually require several months to complete. Having this in mind, the Barr-Bardgett creep-testing apparatus was selected as a first unit of equipment in the creep test room in order that steels might be tested in the specified period of 48 hours, and so hasten the development of steels for special high temperature service. The method of test depends on the accurate measurement of the diminishing rate of creep in a stressed test-piece by means of a steel weigh-bar, so that the rate of decrease of the applied stress is proportional to the rate of creep of the specimen.

The apparatus consists of a rigid rectangular frame which enables a stress to be applied to a test specimen by turning a screw at the top of the frame, the test specimen being

Heat-treatment room showing electrically heated furnaces.

situated inside a thermostatically controlled furnace and connected in series with a calibrated weigh-bar and extensometer. Temperature is controlled by means of a thermostat situated within a special heating coil connected in series with the furnace winding. Uniformity of temperature along the test-piece is obtained by making the furnace winding close at each end. Temperature control and uniformity are further improved by the introduction of a heat-resisting metal sleeve, which surrounds the test-piece. With this arrangement, temperature is controlled to within 0·5°C. and the variation in temperature along the test-piece is less than 2° C. Close attention is being given to the physical chemistry of steel-making processes, and the chemical laboratory is equipped with apparatus for the iodine method for the extraction of non-metallics in steel; equipment for the vacuum fusion method for the determination of oxygen in steel is in course of construction. The Chemical and Corrosion Test laboratories are largely interdependent, in that all corrosion tests of an acid character are carried



Barr-Bardgett creep-testing apparatus.

out in the chemical laboratory, whilst chemical work requiring an entirely fume-free atmosphere is carried out in the Corrosion Test room.

A room is set aside for the preparation of specimens for microscopical examination, containing a motor-driven polishing machine and the usual facilities for etching. For visual examination, bench and portable microscopes are provided, whilst for photo-micrographic work there is a Reichert universal microscope.

The equipment of the Physics Department is housed in a spacious room well provided with bench accommodation. The equipment has been selected to enable the department to provide thermal and physical data for the various works departments, for the service of customers, and for the purpose of research. Dilatometric determinations of the volume changes in steels are carried out on two alternative equipments—the Gale Dilatometer and the Rohn Dilatometer. Coefficients of linear expansion can also be determined.

For magnetic testing the equipment consists of permeameter and iron-loss tester with special generators for the supply of steady D.C. current and steady A.C. current of sine wave form. The permeameter is designed to measure B-H curves and hysteresis loops for all types of steel, ranging from material of low coercive force to that of permanent magnets.

For testing the electrical resistivity the instruments include a Kelvin Double Bridge, and attachments for holding the test-piece and tapping off a definite length on the test, together with a galvanometer. A null method is used in determining the resistance. Two attachments, both designed in the department, are available. The first accommodates test-pieces ranging in size from thin wire to bars 1 in. section, either square or round, and from 6 in. to 24 in. in length, and is for testing at room temperature. The second comprises an oil bath, electric heaters, mechanical stirrers, with suitable devices for holding the specimen and tapping off a convenient length. This apparatus is for use up to 200° C.

The Physics Department is responsible for the calibration and maintenance of all thermo-couples and temperature indicators used in the laboratories. Platinum-platinum rhodium, base metal and Titan thermo-couples are used, and optical pyrometers for the higher temperatures. The standardising equipment consists of a Tinsley potentiometer and accessories, measuring to 0·000001 volt.

Apparatus designed in the Department is under construction for the determination of thermal conductivity coefficients. Of other equipment of special note mention may be made of the X-ray tube. It is of the hot cathode type with water-cooled target and is continuously evacuated by oil pumps. Being entirely demountable, the renewal of the filament or changing of the target is both quick and easy. Designed for use up to 100,000 volts, with a continuous rating of 2 kilowatts, the tube can be used for crystallographic work—determination of the composition of materials, crystal structure of substances, phase changes in metallic alloys and penetration of steel sheet or strip up to $\frac{1}{16}$ in. thickness. The equipment comprises 2 units (1) X-ray apparatus—tube, pumps, high tension and filament transformer; (2) Control cubicle-switches, regulating gear, protective relays and indicating lamps.

The presence of minute cracks, although not observable by visual examination, can be easily detected by magnetic means, for which purpose a magnetic crack detector has been installed. The method is applicable to practically all forms of machined parts made from magnetic materials. Testing is both rapid and reliable, and requires little skill in operation. The test piece is first magnetised and then immersed or swilled with a fluid carrying finely divided iron particles in suspension. The cracks are clearly indicated by the iron particles lining up along the cracks, due to magnetic poles formed at these points. After inspection, the test-piece is demagnetised by passing the test-piece slowly through a solenoid carrying A.C. current.

In its present stage the equipment of the Department represents that necessary for the carrying out of investigations of the type referred to earlier in this article, expeditiously and by established modern methods. It is natural that in the course of time the equipment will be extended to cope with a larger volume of work and with still more modern methods of investigation as these become available.

Rapid wearing generally takes place in the rests or blades used to support the work in centreless grinding machines. These rests are subjected to the grinding action of the work as it rotates and passes through the grinder and are, at the same time, literally bombarded with particles of abrasive material from the grinding wheels. A hard grade of nickel cast iron has been used for these rests and in one case—dealing with valve spindles—eighteen times as many spindles were ground for each dressing of the rest as with the best material previously used, a special steel costing eight times as much as the nickel cast iron part.

The United States Copper Industry

The relatively low average percentage of copper in American ore reserves together with reduced consumption of copper is creating a very real problem in the United States, and the outlook for profitable research is considered.

THE future of the low-grade "porphyry" deposits in the Western provinces of the United States has been a subject of much speculation recently, and conclusions have been drawn from virtually identical data which are diametrically opposed. A recent editorial[1] seems to harmonise with recent information, the conclusions of which are summarised as follows: Three groups of low-cost producers of copper—one in the United States, one in South America, and one in Africa—are, or soon will be, able to produce individually some 800,000,000 pounds of copper annually. The group in the United States (Phelps Dodge, Nevada Consolidated, and Utah Copper) estimates its production cost at 7·86 cents per pound, the South American group (Chile Copper, Braden, Cerro De Pasco, and Andes) at 5·5 cents per pound, and the African group (Roan Antelope, Katanga, Rhokana, and Mufulira) at approximately 6·1 cents per pound. Since world-production capacity is more than twice present consumption operation at full capacity obviously is not feasible. Ore reserves in the United States average about 1% copper, whereas the other reserves are two to four times as rich. A curtailment in production may be expected to increase the disparity in costs, because the company operating on low-grade ore requires a larger plant for a given capacity, and if production is curtailed has a greater amount of capital tied up in non-productive equipment. The magnitude of this effect may be indicated in a recent announcement of the Utah Copper Co., that the increase in cost from 6·5 cents per pound in 1929 to 8·47 cents in 1930 was due solely to the decrease in production from 298 to 161 million pounds. Under curtailed operation, costs even for the low-cost domestic producers may therefore exceed 9 cents per pound.

On the other hand, African producers, except Katanga, have not yet proved their ability to attain their anticipated capacity; labour difficulties, which so far have given less trouble than was originally expected, may become more serious under heavier requirements. Clearly, South American can match low-cost American producers, pound for pound, at a lower cost, and Africa apparently will be able to do likewise in a few years.

Just how the American industry will be affected by this situation depends on the rate at which consumption of copper increases. Evidently, if the present low rate persists for any great length of time, copper production in the United States will gradually cease. Pettengill has stated[2] that the copper industry has nothing to fear if consumption increases in the future as it has in the past. Whether such a continuation may be anticipated is open to question.

Copper consumption depends largely on industrial activity and, within a price range of 8 to 20 cents, at least has been proportional to such activity and independent of the selling price of copper. Graphs showing the consumption of copper for the past few years, corrected to an arbitrary normal business activity, show no increase in rate. Whether consumption will increase with time as in the past is therefore doubtful unless the price should be lowered to some point where the demand curve again shows elasticity, that is, where copper may enter new competitive fields. Just what this price will be cannot be predicted, but if it is 5 cents or below the competition with steel and galvanized iron for certain uses, certainly it would produce some elasticity of demand.

If these conclusions prove correct the copper industry of the United States may look forward to an era of lower consumption and a narrow margin of profit or an era of radically lowered production costs and great expansion. In either case there is a definite incentive for research, which may take the form of increased consumption through (1) development of new uses at existing price levels, (2) reduction of production costs to show increased margin of profit at existing price levels, and (3) radical reduction of production cost to open new competitive fields. The subject is considered at some length by Messrs. R. S. Dean and F. S. Wartman, in "Outlook for Profitable Research in the Metallurgy of Copper," which forms part of the United States Bureau of Mines Report of Investigations 3228, in which these aspects are discussed.

Development of new uses for copper has made progress lately and still offers many opportunities. Progress in this direction so far has depended on newly discovered properties of the metal or one of its alloys, the effect of copper compounds on living processes, or replacement uses in which copper in a form long known is taking the place of some other metal.

The field of substitution has shown the most rapid development, probably because it involves only advertising and development of manufacturing facilities, to attain a commercial basis. Examples of active progress in this field are: Use of copper or brass water pipe, use of copper store fronts and trim, and use of copper as a foundation material for various types of plated ware. As a result of the extensive advertising campaign the public has been convinced of the desirability of copper for such purposes, but actual use in many instances is inhibited by a feeling on the part of the consumer that he is paying an unwarranted premium for copper. Prices actually quoted by local dealers usually confirm this belief, and until the condition either is remedied or justified in the mind of the prospective user, progress in this field will not be as rapid as it might be.

Application of copper to uses arising from newly discovered properties has made much less rapid progress because of the extensive research required and the technical difficulties to be overcome.

The recent introduction of very thin copper sheets, backed with tarred fabric or other material for roofing may be cited as an example of use depending on new discoveries. Another example is the alloying of copper with beryllium to produce a material that may be precipitation-hardened by heat treatment at low temperature. The heat-treated alloy is suitable for springs and similar uses where resilience and resistance to fatigue are required. A small percentage of copper in steel permits the use of low-temperature heat treatment to increase the hardness of the alloy without quenching or other drastic treatment. This should prove valuable where size or shape do not allow quenching.

The use of copper compounds to retard the fouling of ship bottoms and pools is an application to living processes which has long been known. A recent discovery shows that copper paint can also be used for this purpose. It has been found that copper salts in the water in which oysters are grown are of great benefit in causing the young oyster to settle down and take on responsibility.

These new uses for metallic copper, copper alloys, and copper compounds depend on properties discoverable only by painstaking research, which at the beginning could not have been justified easily from the "practical" point of view. Undoubtedly many such possibilities remain undiscovered, and investigation into all possible properties of copper and its compounds will in the end amply repay the

1 Copper Costs, Mining and Metallurgy, Vol. 14, 1933, p. 323.
2 The Copper Industry and the Tariff, Quart. Jour. Econ. Vol. 46, Nov. 1931. pp. 141-157.

industry, both in royalties on patentable ideas and in increased consumption of copper.

It is admitted that the amount of copper which these new uses will require at the beginning will be small. So, too, is the amount of copper in an ordinary electric motor small, but the number of motors made swells the amount used to a large figure. Likewise, the amount of copper going into many new uses could be made into a total well worth attention.

Research in the development of new uses for copper is an indirect method of benefiting the copper producer; it is best followed by the industry as a whole, as it is feasible for the single producer only under protection of brand or trade mark. It is furthermore limited in application since it must be supplemented with continuous expensive advertising.

Reduction of Production Costs.

The relative importance of oxide ore reserves compared to sulphide reserves has declined steadily in recent years; production from such deposits, both actual and potential, is so small a proportion of the total in this country that even an extremely drastic reduction in leaching costs, of which there is no present prospect, would affect the average cost of production very little. Leaching of waste material already treated by some mechanical process offers the greatest opportunity in this field.

The larger part of the copper produced in the United States comes fron smelting flotation concentrates. Exhaustion of oxidised deposits and technical advances in the art of flotation have resulted in many changes in copper metallurgy, but apparently there is room for still further progress both in more complete elimination of undesirable gangue from the concentrate and in the possibility of preparing concentrates consisting of a single mineral. Grinding costs constitute a substantial part of the total for flotation; development of more efficient grinding methods offers another opportunity for investigation.

Conservation of heat, improvement of refractors, and lowering copper loss in the slag, offer the most promise of research in smelting as conducted to-day. No very satisfactory heat balance for the smelting process has been set up because accurate specific heats for many of the materials involved are lacking and because the necessary measurements require more care than the operating department is able or willing to give. One effect of flotation has been to decrease the importance of the roaster and to place a heavier burden on the converter. Moreover, as roasters operate at a relatively low temperature and are insulated, loss of heat at this point is not as great as elsewhere.

A substantial part of the heat content of the waste gas from the reverberatory is recovered in waste-heat boilers. No published figures have been found for the radiation loss, but it may well amount to a third or a fourth of the heat supplied by the burners. This rather large loss could be reduced materially by proper insulation of the furnace, but experience has shown that insulation of furnaces as now constructed increases the rate of deterioration of the arch so much that the net result is a loss rather than a gain. Hence, development of a better refractory is prerequisite to any reduction in this loss. The heat content of the slag discarded from the reverberatory, of course, varies according to the amount of slag produced; flotation has made a great reduction in this loss by reducing the amount of gangue to be slagged.

A more efficient fuel ratio for open-hearth steel furnaces has been attained through the installation of automatic firing and draft control. Since the open-hearth furnace is similar in some respects to the reverberatory used for matte smelting, similar control might be advantageous.

Total costs per pound of copper show that the metallurgical cost does not represent a very large proportion of the total cost, and even a radical saving in this item would not greatly change the total. However, if the margin of profit is small, as it probably will be for some time to come, the possibility of even a small reduction demands consideration.

Radically New Methods.

The extent to which research in reduction of smelting costs by present methods may aid is limited by the fact that direct metallurgical cost is only a fraction of the whole cost. Although such research undoubtedly would be valuable to the individual producer, there is little likelihood that the cost could be reduced enough to open new competitive fields to copper. As already pointed out, a price of 5 cents or below would probably be the maximum.

To accomplish radical reductions in cost, part of the mining, milling, and fabricating costs must be displaced by direct production of fabricated products from the ore, or some type of combination in which the by-products show a considerable profit must be developed. Direct methods of producing sheet have already been discussed; it is conceivable that in combination with leaching in place, mining milling, and smelting might be side-stepped for the production of certain finished products. Developments in this direction would require radical readjustment of production structure, so that research in the direction of combination smelting would seem to offer the best opportunities for immediate acceptance. Summarising their discussion briefly, the authors consider that the best outlook for research in the American copper industry is in the development of radically new methods of producing copper in marketable form. Of such possible methods combination smelting is the most attractive for immediate application.

Developing the Production of Sponge Iron in Russia.

The problem of producing sponge iron by direct reduction of iron ore without fusion, that is, without using coke, has been solved in the Soviet Union. The first experimental plant in which iron will be obtained without the blast-furnace process, started working at the beginning of June in the city of Ivanovo.

The method of direct reduction of iron ore without fusion is comparatively new. Beginning from 1927, various installations were tested in different countries. All these turned out a product less expensive than pig iron, but more expensive than commercial scrap iron. Therefore they had no great industrial importance.

The method is of extreme importance to the Soviet Union where there are large deposits of iron ore and not sufficient quantities of coking coals necessary for the blast-furnace process. The question of applying the new process was raised in 1931, and in 1932 the first steps were taken to put it into practice. A revolving furnace, designed by Trautman and Grum-Grimailo, Soviet engineers, has been installed at the Ivanovo Plant. Their original method has some advantages over those used in other countries, making it possible to produce iron on an industrial scale, at a profit, without the blast-furnace process.

While blast-furnaces require at least 0·8 ton of coke per ton of pig iron, only 0·5 to 0·6 ton of carbon fuel in the form of anthracite smalls, peat or fuel waste is needed per ton of sponge iron melted in the electric furnaces of the new plant. Sponge iron is obtained at moderate temperatures from 800 to 1,050° C., requiring, however, a great amount of electricity.

The production of sponge iron from the Khalilovo ores, which contain nickel chrome, titanium and vanadium, scheduled for the near future, is of particular interest. As proved by laboratory experiment, a most valuable metal can be obtained, which can be extensively applied in the automobile and tractor industries, in aviation and in other branches of the engineering industries.

The National Physical Laboratory

Of immense importance to industry, the work of this Laboratory is primarily concerned with new problems which are continually being presented, in establishing facts which can be applied to industry, and in facilitating the progress of industry by assisting in providing a fuller knowledge of materials and structures.

IN view of the heavy responsibility which rests upon all those concerned with the initiation and carrying out of engineering research it is necessary that fullest advantage should be taken of the latest scientific discoveries in their applications to industry. To achieve this aim it is desirable that industry should be acquainted with facilities available at research establishments and the progress and results of recent researches; and it is also necessary to effect and maintain the closest possible contact and frendly relations between industry and research establishments, so that the immediate and general problems of the former may be known to, and kept in mind by, the latter when planning research programmes, in order that due attention may be given to industrial needs. This aim is being achieved to a considerable degree by the National Physical Laboratory and its rapid growth is some indication of the efforts taken to solve the problems submitted to it.

Although founded as recently as 1900, its purpose being to act as a "Public Institution for Verifying Instruments for Testing Materials, and for the Determination of Physical Constants," the National Physical Laboratory has developed enormously. It originally consisted of a physics department and an engineering department, with a staff numbering 26, of which 11 were scientists. The Laboratory now consists of seven technical departments—physics, electricity, metrology, engineering, metallurgy, aerodynamics, and National tank—and its staff numbers over 600, of which about 160 are scientists.

The work of the Laboratory covers a wide field, including all branches of physics, electricity and magnetism, wireless work, engineering, metallurgy and chemistry, aeronautics, and ship design in relation to form and propulsion. With a very few exceptions, tests of all classes of measuring instruments are undertaken, as far as the available equipment will permit. The special investigations made for firms and other bodies are of a very varied character, and the Laboratory is always ready to give careful consideration to problems or difficulties which may be submitted to it, and to undertake experiments when it is thought that with the facilities at its disposal a solution may be found.

Some Work Done and in Progress.

It is not possible here to review all the work of the Laboratory, but, in the physics department, the application of X-ray methods to industrial problems has been pursued vigorously; tungsten magnet steels have been studied and the investigation has been extended to cobalt steels. A general principle which emerges is that high coercive force is associated with considerable strain, while low hysteresis loss accompanies the strain-free condition. The distortion of the crystal lattice which results when metals are rolled or drawn is now fairly well known. Studies have recently been made by X-ray methods of the distortion in a wire under torsion. It appears that in copper the process is not continuous; at intervals the strain is relieved by internal fracture and recrystallisation, after which distortion again increases. It has also been found that by varying the conditions in a plating bath, electro-deposited nickel can be obtained with crystals having different degrees of internal strain.

Among the many investigations in progress in the engineering department mention may be made that associated with the cracking of boiler plates and joints. It has become apparent during recent years that there exist many points of resemblance between certain types of boiler-plate failure and other service failures which have been traced to corrosion-fatigue. Fatiguing action in the boiler plate at the joint would be caused by variations in stress due to steam pressure differences and also thermal stresses such as arise when the boiler is "let down" at intervals. A machine has been designed and constructed in this department, which can accommodate specimens of boiler plate, welded joints and riveted joints of ¾-in. plate, 12-in. wide by 27 in. long. The specimens are subjected to repeated straining actions while immersed in a tank containing a boiler solution of caustic soda or various salts. The experiments on plates so far completed have yielded farctures of the corrosion fatigue type only: no evidence of failure by "caustic embrittlement" has yet been encountered.

As a result of investigations on fatigue failure and the crystalline structure of metals it appears that the failure of metals in polycrystalline form by fatigue under cycles of stress are determined by the formation of cracks within the constituent crystals; the formation of these cracks appears to depend upon the shearing stresses on certain crystallographic planes in certain crystallographic directions. The failure of metals by fatigue may be seriously accelerated by the presence of corrosive media. An investigation into the nature of this "corrosion-fatigue" effect is in progress and tests are being made on single crystals of aluminium subjected to cycles of stress while immersed in tap-water.

A research on the strength and stability of thin plates, with and without stiffeners, for use in aircraft construction has been in active progress in the engineering department for some time. It is known that the strength of thin sheet metal, when loaded by forces in the plane of the sheet, may be seriously reduced by the occurrence of buckling. Buckling consists in the deflection of portions of the sheet laterally out of its original plane, and results in a reduction of stress in the portions so deflected. Other portions of the sheet, which may be prevented from deflecting, are forced to carry the full stress corresponding to the strain imposed; but the mean stress carried is less than the maximum owing to the smaller loads carried by the deflected portions of the sheet. Failure may, therefore, occur when the apparent stress is very much less than the stress the sheet could carry if it remained unbuckled. Apparatus for the determination of the relation between mean stress and maximum stress for curved rectangular panels has been developed.

The increasing use of higher working temperatures in power and chemical plant necessitates knowledge of the resistance of metals to stress at high temperatures. Considerable research is being carried out at the Laboratory in the examination of the creep of metals under static tensile loads, and also under bending stress, and combined torsion and tension stresses. An investigation of the continuous contraction with time (creep recovery) of materials, resulting from partial or complete removal of tensile stress after a period of creep under stress, is being made. The equipemnt available includes machines capable of measuring rates of creep of less than one-millionth of an inch, per inch per day, on specimens maintained at temperatures up to 800° C.

Many of the fatigue failures that occur in service are of parts that are subjected to two or more stressing actions, and a more accurate knowledge of the strength of ordinary engineering materials under such conditions is very necessary. This applies particularly to the crankshafts of aircraft and automobile engines, which are subjected

to both bending and torsional stressing. Three machines have been designed and constructed in the Engineering Department which are capable of applying to specimens cycles of any combination of simultaneous bending and torsional stresses. An investigation in progress includes a representative range of aircraft and automobile crankshaft steels, and the results will be of inestimable value to designers.

The work of the metallurgy department is probably most widely known in the development of light alloys for aircraft purposes. Other interesting and valuable work, however, includes the development of methods of gas removal from melts to ensure sound castings, the production of refractory materials for use at very high temperatures, and the preparation of very pure metals to act as exploratory bases for new alloys. The determination of oxygen in steel by vacuum extraction forms part of an investigation in progress. The steel is melted in a graphite crucible by means of an induced current of 10,000 cycles frequency supplied by a rotary generator. The gases evolved, which contain the whole of the oxygen originally present in the steel, now in the form of oxides of carbon, are pumped off and analysed.

In many instances, special apparatus has been developed to faciliate studies ; for example, in order to obtain cooling curves of metals with great accuracy, a gradient furnace and thermal curve apparatus has been designed. The specimen examined with this requipment is stationary and the furnace is raised at a uniform rate. A rotating furnace is used for taking thermal curves of alloys which, if allowed to remain at rest, would undergo segreation.

Research constitutes the framework that gives fundamental support to the continued developeent of industry : it leads to discoveries the investigation of which is necessary to establish facts, thus new problems are continually being presented to research workers and the results of their investigations provide the knowledge which can be applied to industry. In this connection the work of the Laboratory is invaluable, not only because of its fundamental research, but because of its subsequent investigations which lead to the application of a discovery to industry.

Production of Soviet Industry.

The Soviet output of iron and steel shows further increase during the month of May. The average daily output of iron was 29,450 tons. This is 3·8% more than in April, and 57·6% more than in May 1933. The plan for pig iron, however, was only carried out to the extent of 98·5%. The average daily output of steel during May was 25,400 tons, as against 26,000 tons in April. The average daily output of rolled steel was 2·7% higher than in April, but the plan for the month was only carried out to the extent of 91·7%.

Some branches of the non-ferrous metal industry also had increased outputs in May. The production of copper was 10% higher than in April, and the aluminium and gold industries had more than reached expectations. The automobile and tractor industries had carried out their plans completely. The average daily output of motor-lorries in May was 184, as against 177 in April, while the output of tractors rose from 261 per day in April to 268 per day in May. The production of harvesters had increased from 457 in April to 884 in May, and binding machines from 68 to 114. There has been a decline in the output of coal with an output of 7·1 million tons of coal in May, being 93% of the plan.

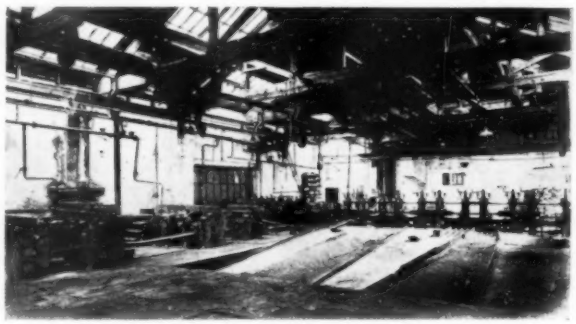
Over 150 vessels have been converted to the use of superheated steam by the North Eastern Marine Engineering Co., Ltd., and in this way much old tonnage has been rendered workable again at a profit. In these installations the internal fittings of all valves passing superheated steam are of Monel Metal to give resistance to the cutting effect of the steam, and the high temperatures and pressures employed.

MODERN STEEL WIRE ROPES.

ONE of the most interesting and important industries starting from the steel billet is the manufacture of wire rod and wire, as well as wire ropes, used for all kinds of purposes, including winding and haulage for mines, as well as logging, ships' rigging and hawsers, lifts, cranes, aerial ropeways, cable tramways, and steam ploughing.

In this connection some notable ropes have been turned out during the past year or two by the Whitecross Co., Ltd., of Warrington, who have been making wire ropes since 1864. Also they carry out themselves at their works the whole of the operations, that is rolling the billets into rods, using a series of 17 roll passes, special heat treatment or "patenting," along with pickling where necessary, cold drawing of the rods to wire, using a series of cast steel or alloy dies, forming the wires into strands and closing the latter into the finished rope.

The firm have for example supplied a steel winding rope to a Belgian colliery, which is one of the largest in Europe, being 3,300 ft. long, and 8 in. in circumference, having an actual breaking load of 280 tons. This rope was specially



Rod rolling mill at Warrington.

designed and constructed to operate on the Koepe system of winding, using a single rope driven by a friction wheel, with a cage attached to each end. Essentially the design of the rope is on the compound, multiple-strand, non-rotating, self-tightening principle, the outer layer of strands giving a smooth interlocking outer surface to the rope which prevents the covering becoming slack at any period of working. In general the core layers of the rope are closed in the opposite direction to the outer strands, which results in a scientific balance between the constituent strands and eliminates all tendency to spin or rotation.

Another notable winding rope 6,600 ft. in one continuous length has been supplied to a gold mine on the Rand, having an actual breaking load of 70 tons (156,800 lb.), representing a useful load, both skip and rock, of 6·9 tons (15,500 lb.). So far as actual length is concerned, however, one of the most remarkable examples is a wire rope of seven miles without joints or splices, made by the firm for the Glasgow passenger sub-way, which operates on the cable tramway principle. In this case the rope weighed over 56 tons, being $4\frac{5}{8}$ in. circumference, constructed of six strands each of 19 wires with a manilla core, the working speed being $13\frac{1}{2}$ miles per hour.

It should be pointed out also that one of the main advances in the field of wire rope making during recent years is the elaborate scientific control by chemical analysis, examination under the microscope, and physical tests carried out at each stage of the manufacture.

A well-known automobile manufacturer uses a hard-faced hot trimming die for a ring gear forging for trucks. This die is $10\frac{3}{16}$ in. diameter, and made of vanadium steel, with a small amount of stellite applied to the edge. The plain vanadium steel dies gave 2,000 pieces per grind, whereas 43,000 pieces per grind have been obtained with the hard-faced dies.

METALLURGIA
THE BRITISH JOURNAL OF METALS.

INDUSTRY'S BAROMETER.

PROBABLY the most informative index to industrial conditions is that indicated by fluctuations in employment, and the recent quarterly returns of the International Labour Office at Geneva definitely show a continuation of the upward tendency which has been a feature of world industry since the early spring of this year. Most countries show further improvements in unemployment. France, the Irish Free State, Poland, and Bulgaria are the exceptions. The United States show the greatest increase in the number of people at work—nearly three millions in a year. This is undoubtedly due to the operation of the New Deal legislation, but it is noteworthy that the number of unemployed is still of colossal dimensions, being given as 10,616,000. Germany's big drop —from 5,534,000 in 1933 to 3,394,327 in May last—is due, of course, to the drastic measures taken by the Government to find jobs, but it is doubtful whether these measures increase the prosperity of the country. Women were displaced by men, firms were forced to adopt a system of sharing between their staffs and the unemployed, and wages were reduced. But the general drop in unemployment throughout the world certainly indicates that trade is improving.

The most recent figures regarding unemployment in the United Kingdom show a slight increase—for the first time since the seasonal rise recorded in the January figures. Previous to that, the fall had been steady since the parallel increase in January, 1933. The present check seems to be entirely due to increased unemployment in the coal industry —which the hot weather may help to explain—and to a slump in the wool trade. It is noteworthy, however, that engineering is giving increased employment, and so are the iron and steel and even the shipbuilding industries. Thus the recent figures do not necessarily mean more than a slight and possibly quite temporary arrest in the upward trend of employment. Actually, the Board of Trade index in industrial production is fast approaching the high level of 1929. The number of people in empoyment to-day is only 10,000 below the average figure for 1929. Thus, Britain is almost back to the last " boom " period. Yet there are still two and a quarter million still unemployed and the poverty in a number of derelict areas is a standing reproach to statesmanship in an era of potential abundance. This fact seems to reflect upon the use of the word recovery, which is claimed to apply to British industry, but so much has been achieved since the period of crisis, that recovery is a fact.

The task of reconstruction cannot be accomplished in a day, but it has been commenced, and the persistent reorganisation of the economic life to meet the changed conditions will continue to bear fruit. There is a certain gratification in the substantial progress already made, but Britain cannot afford to take a complacent view of the future, as there are no grounds for believing that a state of flourishing activity will return if matters are left to take their own course. The basic causes of recent progress in Britain have been the adoption of a tariff and the abandonment of the gold standard. The former is helping manufacturers to re-equip factors and to produce goods previously imported, while the latter has assisted in balancing the forces of deflation, thus increasing the British competitive position in the world market. Much of the improvement is of a domestic character, however, because high tariffs, exchange restrictions, and import quotas are firmly established in the principal Western markets, and, with the rapidly growing pressure of Eastern competition, make overseas trade extremely difficult. Yet Britain has recovered, during the present year, her leading position as an exporting nation.

In Britain, as Sir William Larke has pointed out, steel production may be taken as an index of general economic well-being, and the iron and steel trades, together with their cognate industries, reflect confidence in the future. Even before the general depression the state of the British iron and steel industry was far from satisfactory, and once the depression set in it was obvious that this industry would feel the effects of intensified competition. Continental steel manufacturers offered steel at prices which did not cover production costs, and even in a shrinking market they captured an increasing share, so much so that before the scheme of protection was put into operation the proportion of steel imports amounted to 55 per cent. To-day the change is apparent, and British production of iron and steel is now almost double the average manufactured in 1931, and exceeds the monthly average during 1929.

The derelict areas still provide a problem of great importance, and it is some consolation that the British Government has taken steps to grapple with it. Certain areas have benefited least from general recovery, and shortly it is expected that four special investigators, who were appointed to inquire into the position of distressee areas, will present their reports. These reports will be of special interest because they will represent separate inquiries conducted in areas where the problems have a certain similarity. They are a direct result of the whole trend of world economic changes since the war, and the reorganisation of economic life in progress because of these changes must bring to the relief of existing poverty stricken areas similar possibilities of recovery as have been granted to more fortunate areas. The problem will be difficult to solve, but it is a challenge to the Government, and demands a policy which will effect systematic progress in all the industrial areas.

That considerable development has already been made on systematic lines few will deny. The policy of trade agreements within the Empire and with foreign countries has been pursued with vigour, and although so far as trade figures are concerned, the Ottawa agreements have proved more useful to the Dominions overseas than to Great Britain, it is a form of co-operation which should be fostered in an effort to adjust the balance of trade. The policy adopted is based on the elementary principle of buying from those countries which use British commodities and products, and the further development of this policy, with the gradual improvement in world conditions, must tend to increase trade overseas, and a reliable rise of the world's trade barometer will depend upon this spirit of co-operation by which depressed as well as the prosperous areas can appreciate trade improvement.

SHIPPING AND SHIPBUILDING.

BOTH the shipping and shipbuilding industries are directly concerned by the offer recently made by Mr. Runciman on behalf of the Government. When he made his speech in the House of Commons, Mr. Runciman emphasised that any plan to assist shipping must also benefit the shipbuilder. The plight of that industry is admittedly deplorable, as illustrated by the North-East Coast, one of the chief shipbuilding centres. In the relatively prosperous years 1924 and 1929 the number of workers actually employed in the industry in this area was nearly 40,000. By 1931 the figure had fallen to about 15,000, and this out of a total of over 50,000 workers associated with the industry. But the scrapping and building scheme—the building of new or the modernising of existing tonnage where three times as much tonnage is scrapped—was not well received except by one section, which has always been in favour of a scheme of this kind if a suitable one could be devised.

Originally, it will be recalled, Mr. Runciman refused the request of the tramp shipowners for a straight subsidy of 10s. per gross ton to be enjoyed by all vessels in employment. Instead he proposed to give the shipping industry cheap loans, to be used to build up-to-date cargo tonnage on condition that so many old vessels were scrapped for every new one built. Obviously such a scheme offered distinct possibilities to the shipbuilding industry, but the shipping industry was not interested. Although the policy of scrap and build might stimulate shipyard employment, the shipowners considered that even if they possessed new and more economical vessels there would be no advantage as long as they continued to be undercut by continued, or perhaps intensified, subsidisation by foreign governments of their competitors abroad.

In view of the mixed reception of the original scheme, Mr. Runciman supplemented this by a proposal to allocate two million pounds a year as a tramp shipping subsidy for defensive purposes, but the subsidy will not be given unless steps are taken by the industry to prevent it being dissipated by domestic competition between the British tramp ships themselves. This proposal goes near to meeting the wishes of the owners of tramp ships, and since the scrap-and-build offer is also included in the White Paper an effective solution to the problem may finally be agreed upon. It is left for the shipowners to work out a satisfactory scheme from the policy defined in the White Paper before the Government will put the arrangement into operation, in which case it is to operate experimentally for a year.

Given a fair field there are few British shipowners who would desire favours from the Government, but the struggle for freights has become so intense during recent years, fostered by the uneconomic policy of subsidising shipping, practised by foreign governments, that some means must be devised to prevent further losses to British shipping. It is not likely that a grant of two million pounds will lead to the abolition of subsidies by other countries; it may, in fact, increase this form of economic war, but it is questionable whether any other method would give reasonable facilities for fair competition. Shutting out subsidised shipping from British ports, or the imposition of heavy discriminatory port dues against the shipping of countries operating with the assistance of subsidies, has been suggested. Such a method would only increase the difficulties of normal trading without giving any appreciable advantage to British shipowners, and it would certainly cause endless political complications. The barriers to normal trading, as a result of tariffs, exchange restrictions and quotas are already too severe without adding to them.

Mr. Runciman confidently expects that the policy agreed upon by the Government will lead to organisation of tramp shipping. It would be too much to hope that an international agreement could be entered into with regard to tramp shipping, on the lines already arranged between the owners of tankers throughout the world, because of the complexities of this section of the industry, but a similar scheme for tramp shipping would be of immense value; this proposed subsidy to British shipping gives a bargaining weapon which should assist the Chamber of Shipping in coming to some such agreement. Failing international agreement there should be little difficulty in British shipowners organising themselves to form a single unit; the subsidy would then be of real value in the competition against the subsidised shipping of their competitors. There should be no delay in coming to some amicable arrangement, because any undue delay is bound to influence shipowners contemplating new tonnage, and will hold up the placing of orders. Despite the improvement in ship construction which is indicated in the recent returns issued by Lloyds Register of Shipping—an increase on the work in hand on March 31, of 105,702 tons.—the shipbuilding industry is badly in need of work which should result from a satisfactory arrangement, and although the time limit seems to be totally inadequate, the successful operation of a scheme would lead to the continuation of the subsidy until conditions in the two industries were considered to be relieved by some international agreement regarding shipping subsidies.

Forthcoming Meetings

French Foundry Association.

THE Thirteenth Annual Congress of the Association Technique de Founderie will be held at Nancy on July 20 and 21, at which many technical papers will be presented covering a wide range of subjects both in ferrous and non-ferrous fields.

It is noteworthy that the exchange paper from the Institute of British Foundrymen will be presented by Mr. E. Longden, Foundry Manager of Craven Bros., Ltd., Manchester, the subject of which will be "Some Factors which Influence the Density and Soundness of Iron and Non-ferrous Castings." Other exchange papers include one from the American Foundrymen's Association by Mr. H. Walther on "Study on the Fabrication of Cast and Electric Iron"; the Belgian Foundry Technical Association on "The Influence of Linseed Oil Used in Sand Preparation and Its Results on the Texture and Mechanical Properties of Cast Iron"; and from the Czecho-Slovakian Foundry Technical Association by Professor Pisek.

Institute of Metals.

This year's annual autumn meeting of the Institute of Metals will be held in Manchester. The twenty-sixth gathering of the series, it will take place from September 3—6, under the chairmanship of Dr. Harold Moore, C.B.E., president of the Institute. The proceedings will begin in the evening of September 3, with the delivery by Dr. J. L. Haughton of the thirteenth autumn lecture on "The Work of Walter Rosenhain." Dr. Rosenhain, F.R.S., who died in March last, was a past-president of the Institute and a world-famous metallurgist.

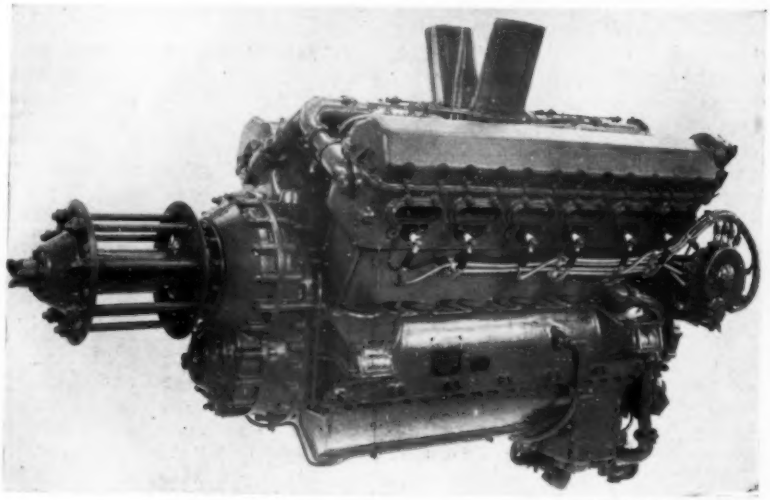
On September 4 the assembled members will be given a civic welcome by the Lord Mayor of Manchester before beginning the discussion of a series of scientific papers relating to various phases of metallurgical work. Further papers will be presented on the following morning. Works visits are being arranged. Persons wishing to take part in the proceedings should communicate with the Secretary of the Institute of Metals, 36, Victoria Street, London, S.W. 1.

ALLOY STEELS TO-DAY

By Professor D. Hanson, D.Sc.

To-day engineering has achieved remarkable progress, but the evident marvels of modern engineering are expressions of less evident materials which are the marvels of metallurgical science and art, and the profound influence of alloy steels on the progress achieved is now beyond doubt. They have been developed from intensive scientific research, and commercial tests to which they have been submitted indicate that they possess special properties desired by the engineer, and are being applied with increasing success in overcoming modern engineering problems.

IN order to fully understand the wide range of alloy steels now in use, and the varied purposes to which they are put, it is necessary to have some understanding of what they are, and, in particular, of the rôles played by the various alloy elements used. Steel is essentially an alloy of iron and carbon, and its characteristic properties and alteration by heat-treatment depend on the fact that the carbon may exist in different conditions in the material. We have, firstly, the condition in which the carbon takes the form of small particles of carbide of iron embedded in crystals of the iron itself; these are the pearlitic steels, characteristic of slowly cooled carbon steels, which are relatively soft and ductile, and are so largely used for structural work and other parts in which a moderate degree of strength and toughness is required. Secondly, we have the condition in which the carbon is dissolved in the alpha variety of iron; these are the martensitic steels, obtained by the rapid cooling or quenching of carbon steel, and represent the alloy in its hardest form; by appropriate tempering, the degree of hardness can be regulated to any desired extent. The third condition is that in which the carbon is completely dissolved in the gamma variety of iron, the so-called austenitic steels, which are only found in the presence of appropriate amounts of certain alloying elements; they are harder and tougher than the pearlitic steels of the same composition, and possess a considerable capacity for cold work, but none of them has the intense hardness associated with the martensitic steels. In considering the action of alloying elements, it is essential to bear in mind the capacity of steels for existing in these three separate and distinct conditions.



By courtesy of Rolls-Royce Ltd.

The light yet powerful aero-engine, which has contributed so largely to the conquest of the air, would have been virtually unattainable by the use of carbon steels alone.

The Action of Alloying Elements.

The influence of alloying elements on steel may be considered under two main headings:

(a) Their effects on the transformations of the steels;
(b) Specific effects characteristic of the alloying elements used.

Influences coming under both these headings are important in relation to the use of alloy steels, but those falling under heading (a) are particularly vital, since they govern some of the most extensive uses of alloy steels in practice. One or two simple examples will illustrate their importance. Every engineer knows that, whereas it is quite an easy matter to harden a small piece of carbon tool steel, and to obtain it in its hardest possible condition, it is a very different matter to secure the same result with larger articles such as die blocks or other complicated or massive tools. Difficulties arise not only in securing the requisite hardening effect with larger masses, but severe warping and cracking are likely to occur, especially with articles of complicated shape, due to the severe stresses set up by the water quenching process which must be used.

These difficulties are due to the fact that the critical cooling velocity for carbon steels is very high; in other words, the steel must be cooled very rapidly through its critical point if the hard or martensitic condition is to be obtained, and unless this condition results, the whole process of heat-treatment fails. With ordinary carbon steels it is, in fact, difficult to obtain complete hardening throughout any piece which exceeds about an inch in thickness, and, if the manganese content be low, even this small size may be too large to enable proper hardening to be obtained. The following figures show the differences in hardness obtained at the centre of different sized bars of the same steel treated in exactly the same manner.

Steel.	Size of Bar. Inches Diam.	Heat-treatment.	Brinell Hardness. Number.
.85% C.	9/16	Water quenched from 850° C.	555
	2	ditto.	311

When still larger pieces are involved, as, for example, forgings of large size, the rates of cooling which can be obtained, even by the use of water-quenching, are so far removed from the critical quenching velocity that they have little effect on the structure or properties of the material; carbon steel in large masses is quite insensitive to heat-treatment, and the improvements in properties obtainable in the case of small samples cannot be achieved.

In some cases great hardness is not required in the final article; many structural parts are used in the hardened and tempered condition in which intermediate properties are desired. Even in such cases the restrictions imposed by the mass of the article are important, since it is impossible to obtain the best combination of mechanical

properties (strength, toughness and ductility) unless full hardening has been obtained during the quenching process itself.

Most of the alloying elements used in steels reduce the critical cooling velocity for hardening, that is, they make it possible to harden the material when slower rates of cooling are used, or, alternatively, to secure the fully hardened condition in large masses. Thus, for all except the smallest parts, the use of an alloy steel is essential if the advantages of heat-treatment are to be obtained. Even where the use of alloy steel is not made essential by the difficulty of securing complete hardening by quenching, it is often advantageous in reducing the risks of cracking and warping by allowing substitution of oil-quenching for the more drastic process of water-quenching.

Alloying Elements and Hardening.

Although the number of elements added to steel is relatively small, there being only 7 or 8 which find extensive application, nevertheless, when we take into account the wide range of carbon contents, the varying amount of each alloying element and the many combinations of alloying elements used together, it is found that the total number of alloy steels now in use is very great, running into hundreds of different compositions. A detailed consideration of these steels, or even of all the main types, is quite out of the question in a short article. It is only possible to consider broadly the general effects of the principal elements used in order to give a rational understanding of the causes which have led to the development of alloy steels as a class.

The *intensity* of the hardening effect which can be produced in any steel, depends more on the carbon content than on any other individual factor; in the absence of this element, the amount of hardening that can be obtained by quenching is small or absent, no matter what other constituent is added to the steel, and the intensity of the hardness obtainable increases with rise of carbon content. The *ease* with which hardening may be obtained differs enormously from steel to steel and depends primarily on those elements other than carbon which are alloyed with it. Manganese, chromium, molybdenum and nickel are all very effective in facilitating hardening, or, in other words, reducing the critical cooling velocity necessary for complete hardening to be obtained; indeed, by the addition of a sufficient quantity of alloy, hardening may be obtained even with quite slow rates of cooling, such as are associated with the normal cooling in air of quite large masses.

The air-hardening steels contain one or two more of these elements in sufficient quantity to produce this effect; for example, a 0·4% carbon steel, containing 5 to 10% of manganese becomes martensitic when cooled at ordinary rates without quenching; 8 to 20% of nickel produces a similar effect. In practice, for reasons associated with the specific influences of the individual metals themselves, it is more usual to secure air-hardening properties by the combined influence of two or more added elements; a steel containing 0·3% of carbon, 3½ to 5% of nickel, and 1·0 to 1·5% of chromium is typical of air-hardening steels commonly in use, and, in this material, cooling in air is just as effective as quenching in oil in producing a hard product, while, of course, the dangers of cracking and warping through quenching stresses are largely eliminated.

Similar but less intense effects are produced by the use of vanadium, tungsten or cobalt. Silicon on the other hand, acts in the opposite sense, making the suppression of the normal transformation more difficult by raising the temperature of the critical points into a region in which internal changes of this kind take place extremely rapidly. In practice, nickel, chromium and manganese are the most important alloying elements affecting ease of hardening; molybdenum is also effective, and it is employed to some extent, usually with nickel and chromium, but its use is limited by its high cost.

The complete suppression of all transformations in cooling with the formation of austenitic is specially favoured by manganese and nickel; in a 0·4% carbon steel, more than 10% of manganese or 20% of nickel is effective in this respect, while the influence of chromium is of the same order as that of nickel, although it varies more with the carbon content than does the effect of nickel. Nickel, in fact, readily induces austenitic conditions when the carbon content is quite low, whereas this effect cannot be produced in low carbon steels by the influence of chromium alone, except when rapid cooling methods are employed. The influence of molybdenum, vanadium, tungsten and cobalt in producing austenitic steels is quite small within the limits employed in steel manufacture. Silicon, on the other hand, acts on the opposite sense to nickel and manganese in rendering more difficult the production of austentite, and, indeed, when present in sufficient amount, prevents this constituent forming under any circumstances. Nickel and manganese are, therefore, the principal alloying elements employed when the austenitic condition is desired.

Manganese is used, as in Hadfields' well known manganese steel, where a product involving high resistance to wear is needed; its suitability in this connection is largely due to the instability of the austenitic structure under cold work or distortion, when it reverts to the martensitic condition, so that such a steel subjected to abrasion develops an intensely hard skin possessing the highest possible resistance to wear, while retaining great toughness and ductility in the mass of the metal. The nickel austenitic steels are more stable and, indeed, by suitable adjustment of the composition, can be rendered completely stable at ordinary temperature, when they may be subjected to severe cold-working processes without appreciable change in their hardness except that due to cold work alone. Frequently a combination of nickel and chromium is employed in practice in the austenitic steels, some of the nickel being replaced by chromium in order to develop corrosion-resisting properties to a high degree. The well known 18/8 alloy containing 18% of chromium and 8% of nickel is a case in point, but many other variations in composition, such as 13% of chromium and 13% of nickel, or 18% chromium and 14% nickel, are also used.

In addition to their effect on hardening power, alloying elements may act on the carbon in the steel producing carbides other than Fe_3C. The production of such constituents may influence the steel in a number of ways; as a rule, such carbides differ from iron carbides in their solubility in iron; tungsten carbide, for example, requires a much higher temperature for complete solution than does iron carbide, and a tungsten steel contains undissolved particles of carbide after the ordinary heat-treatment involving iron carbide has been applied to it. Particles of free carbide, as these are called, constitute hard spots in the steel, whose presence may or may not be desired. In structural steels, for example, in which the greatest possible homogeneity is normally required, the presence of such a constituent would be undesirable, but in tool steels, particles of free carbide frequently contribute to the cutting properties and are, therefore, advantageous. Tungsten, molybdenum, vanadium, manganese and chromium all facilitate the production of free carbides by combining with some of the carbon present in the steel. Nickel and silicon do not, themselves, form carbides; on the other hand, they tend to decompose iron carbide itself. This effect of nickel is not encountered in the main with steels, but in the case of silicon, the influence in this respect is particularly great, to such an extent that when used as an alloying element in steels required to be subjected to a hardening treatment, silicon must be counteracted by including a carbide-forming element such as manganese, as in silico-manganese spring steels, in which 2% of silicon is usually associated with 1% of manganese. The carbide forming qualities of alloying elements are principally

utilised in connection with cutting tools, in which chromium, molybdenum and tungsten largely figure.

It is interesting to note the special position which nickel occupies in relation to the influences discussed above. It has a marked effect on hardening power, and, in suitable proportions, confers either oil-hardening or air-hardening properties on steel; it is the most effective element inducing austenite formation and producing a stable austenitic condition capable of withstanding cold working operations without reversion to the hard state. At the same time, it does not form hard carbides, and interferes little with the normal reactions taking place in steel itself, and in particular does not form hard carbide inclusions characteristic of some of the alloy elements. These properties give it a wide range of uses, and are responsible for many of the applications which it finds in practice.

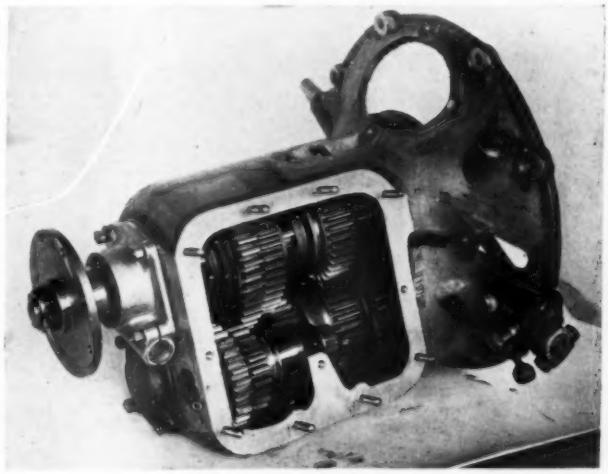
Specific Effects of Alloying Elements.

In addition to the above general effects, each alloying element has certain specific effects that are its own individual characteristics and cannot be classified under any general heading. Only the most important of these can here be mentioned, but some are so outstanding as to require consideration in any treatment of the subject "alloy steels." Perhaps the most remarkable is the influence of chromium on the resistance to attack by chemical agencies, particularly oxidation and a wide range of acids. This is, without doubt, connected with the great capacity of this metal to form protective films under the influence of a wide variety of conditions. The stainless and rustless chromium-containing steels owe their properties to this quality in the material, and the specific nature of the effect in so far as chromium is concerned is well brought out by the similarity of the metal itself, in the form of chromium plate, with the stainless steels, the corrosion-resisting properties of the two being closely similar in their general characteristics. It is indeed fortunate that the element which, above all others, confers such marked resistance to corrosion, is also one which has most useful and beneficial influences on heat-treatment and mechanical properties. The film-forming qualities of chromium are also well maintained when the steel is subjected to oxidation at elevated temperatures, and the chromium-bearing steels are finding useful application by virtue of their resistance to scaling.

Tungsten and molybdenum have certain important specific effects which are so similar in character that they may be classified together. Both these elements confer on steel great stability under heat, particularly by maintaining high mechanical strength and hardness at high temperatures; this is no doubt largely due to their very high melting points and intrinsic hardnesses. This quality is particularly valuable in connection with cutting tools, since steels containing these elements in sufficient quantity retain their strength and hardness even at a red heat, and the development of high-speed cutting steels depends mainly on this characteristic. A similar effect, also of considerable practical importance, is to be found in the influence of these elements in raising the tempering temperature at which the martensitic constituent decomposes by precipitation of iron carbide.

Both tungsten and molybdenum greatly raise the normal tempering temperatures of steels, even when present in quite small quantities, and this makes possible the development of structural steels possessing high elastic limits which are stable over a wide range of temperatures; the use of quite small amounts of molybdenum, in particular as an addition to high-grade alloy steels, has had most beneficial effects on this account.

Nickel is perhaps the most versatile of all the elements added to steel, and it has a number of most important specific effects. Nickel unites with iron or steel in all proportions, and useful alloys are obtained with practically every conceivable ratio of the two elements. Low percentages of nickel increase the strength, yield point and hardness without a corresponding loss in ductility, in both the annealed and heat-treated steels; steels containing 20 to 30% of nickel are non-magnetic after cooling at ordinary rates to atmospheric temperature, and steels within this range find many applications for which a non-magnetic material of high strength is required: with between 30 and 40% of nickel, the coefficient of linear expansion is very low, and 35 to 36% of nickel produces an alloy which has practically a zero coefficient. An alloy containing 50% of nickel has high permeability at low field strengths, and it and other combinations containing still more nickel are finding increasing application on account of their magnetic properties. The possibility of adding considerable amounts of nickel to iron without reducing ductility is no doubt due to the fact that iron and nickel combine in all proportions to give ductile workable alloys; nickel in the quantities added in the alloy steels dissolves in the iron without forming a carbide and furnishes a strong ductile basis very suitable for still further improvement by the addition of the alloying elements of the carbide-forming group. Nickel, in fact,



By courtesy of Associated Equipment Co. Ltd.

The modern gear-box is a triumph in which the combination of hardness, toughness and strength of alloy steels is amazingly exemplified.

appears to exert its own improving tendency without affecting the specific effects produced by other alloying elements, and it is, no doubt, for this reason that it enters so largely into the alloy steels.

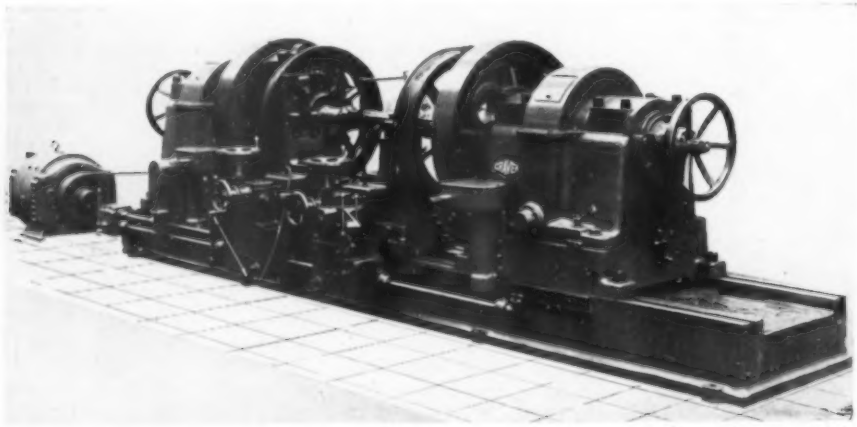
The Uses of Alloy Steels.

The above account of the general principles involved in the use of alloying elements is designed principally to give a proper understanding of the factors responsible for the use of these steels for the many and varied applications which they satisfy in practice. It will be clear from this discussion that the possible number of alloy steels is legion. Many of these will differ so little from one another that they may be regarded as mutually replaceable, and the Engineer must be faced with considerable difficulty in making any selection with only the conflicting claims of numerous manufacturers' catalogues to guide him. In making his selection he will be wise in the first place to make certain that the composition which he chooses is one that is suitable from the point of view of heat-treatment. In this, the size of the article involved is the principal factor, and he would do well to make certain that the properties can be obtained, particularly if the articles are complicated in shape, with mild quenching treatments in order to avoid troubles due to cracking and warping.

Next he will take care that the composition chosen is one suitable for the particular conditions of service which must be encountered; these differ enormously from case

to case and the qualities desired may involve resistance to chemical attack at ordinary or elevated temperatures, resistance to wear, to shock, strength at high temperatures, and so on, each of which calls for special characteristics in the material. Thirdly, he will be wise to see that, once the principal requirements have been met, the steel possesses to as high a degree as possible the best combination of properties consistent with his requirements. For example, great hardness and resistance to wear can be obtained in a variety of ways among the alloy steels, but the toughness and ductility of alternative alloys having the same hardness vary enormously, and it is in the proper selection of materials for such purposes that the Engineer and Metallurgist must show their skill in deciding the most appropriate compositions and heat-treatment to be used.

Finally, while different steels no doubt vary appreciably in their first cost, it should be borne in mind that by the time the various processes of heat-treatment, machining and otherwise fabricating have been applied, the actual value of the raw material is relatively unimportant, and that it is far better to select the right material and to give it the best treatment than it is to make an unsuitable first choice.



By courtesy of Craven Bros., Ltd.

The use of alloy steels in machine tools, not only in the cutting appliances themselves, but also in the general construction of the machines, has played a very important part in the speeding-up of manufacturing methods, and reduction in manufacturing costs.

Since their introduction about 50 years ago, alloy steels have gradually extended their usefulness, until now they enter into so many branches of engineering and are used for so many purposes that any classification on broad lines is totally inadequate to indicate the many functions which they fulfil. At first they were used only for a limited number of special applications, as, for example, for the manufacture of tools, crusher jaws and other special purposes for which their properties made them specially suitable. Nickel and nickel-chromium steels soon found application in the manufacture of guns, armour-plate and similar military equipment, and very large tonnages were absorbed for these purposes. The development of high-efficiency machines which has taken place so rapidly during the last 30 years has necessitated the use of materials of the best possible quality owing to the high stresses involved; indeed, the alloy steels have been so widely used in the development of machines of all kinds that they must be regarded as having played a most important part in the engineering and mechanical developments of our times.

The internal combustion engine depends largely on alloy steels for its present efficiency, while the light yet powerful aero-engine, which has contributed so largely to the conquest of the air, would have been virtually unattainable by the use of carbon steels alone. In all such machines, as in many others, in which a high performance is required, the important highly stressed members are invariably made of alloy steels; crankshafts, connecting rods, camshafts, and so on, give their high performance by virtue of the alloying elements which they contain; the modern gearbox is a triumph in which the combination of hardness, toughness and strength of alloy steels is amazingly exemplified, while the alloy steel poppet valve, though only a small part by weight of an internal combustion engine, by virtue of its stability and strength at high temperatures, has had a greater influence than any other part of the engine on performance and efficiency.

In much the same way, other types of machines, such as pumps and compressors, steam and electric locomotive and stationary engines, crushers and mixers, as well as the hundreds of special machines used in the manufacture of the necessities and luxuries of the modern state, all owe some of their usefulness to the special qualities of the alloy steels which now enter so largely into their construction. The use of alloy steels in machine tools, not only in the cutting appliances themselves, but also in the general construction of the machines, has played a very important part in the speeding-up of manufacturing methods and reduction in manufacturing costs, while the application of alloy steels for such purposes as the manufacture of dies, forming and stamping tools and the like, has also contributed in the same direction. It is no exaggeration to say that the present use of alloy steels is an important factor contributing to the enhanced standard of living and the numerous luxuries and conveniences which we enjoy to-day.

The development of stainless and corrosion-resistant steels is one of the most important of recent achievements, and the application of these materials within recent years has had far-reaching effects. The austenitic stainless steels containing substantial amounts of both nickel and chromium are rapidly finding extended uses in an immense variety of directions, and seem likely to prove more and more important in the future. They are already replacing non-ferrous materials such as copper, brass, and other alloys, in the manufacture of articles of a decorative nature in which freedom from tarnish is important, while their use is extending with great rapidity in connection with manufacturing processes of all kinds. The chemical industry already absorbs a big tonnage of such materials for the manufacture of special plant, while they are proving to be specially suitable in the manufacture of good products on account of their great resistance to attack by organic acids.

It would be possible to extend the list of examples of applications almost without limit. Enough has, however, been stated to demonstrate how vital a part these materials play in our modern life, and to indicate the debt we owe to those metallurgists and manufacturing firms whose efforts have made these developments possible. Much more remains to be done, both in the discovery of other alloys and in extending application of those already known, and there is every reason for believing that alloy steels will contribute more and more to the amenities of life and the comforts of our civilisation.

[We are indebted to the Mond Nickel Co., Ltd., for permission to publish this, the second of a series of articles, specially written for them on alloy steels, and which will shortly be published as a brochure by the Bureau of Information on Nickel, Thames House, Millbank, London, S.W.—Editor.]

The Classification, Properties, and Utilisation of Non-Ferrous Scrap Metals and Alloys—Part 2

By A SPECIAL CORRESPONDENT.

The wide variety of non-ferrous alloys now employed, and the increasing need for accuracy in their composition, creates a very real difficulty in their proper utilisation when the articles for which they have been used become scrap metal. In this article the author discusses the problem with a view to the more profitable use of scrap bronzes and brasses.

PHOSPHOR bronze must not be confused with material from which valves are sometimes made, otherwise appreciable loss may result. It may easily be recognised by its extreme fluidity in the molten state. Bearings which are made of a high tin alloy exhibit a whitish, close-grained fracture, but should this be speckled with reddish or brownish particles or surfaces, this is a sign that it has been oxidised excessively, and such materials need to be treated in some way for the removal of these impurities. Large castings, such as propellors, are generally composed of manganese bronze, and if when they are heated and hammered they do not break, this is almost certain proof that they do consist of manganese bronze. From these notes it is clear that considerable accuracy can be attained in the sorting of various non-ferrous metal scrap by a considered examination of fractures and surfaces of material. This is very fortunate, since it is quite often possible to obtain materials for the foundry at a considerably lower price if they are bought as miscellaneous scrap and sorted by the user, than if ingotted metal or sorted scrap is purchased from the scrap merchants.

Generally, if scrap alloys and metal are carefully and properly melted the oxidised portions cleaned and skimmed in the molten state, castings are obtainable which are quite as good in every way as those obtainable from the more expensive virgin metals. It should be borne in mind, however, that brass which is high in iron or containing aluminium generally gives castings which are not very sound; such castings could not be generally expected to withstand heavy air or hydraulic pressures. For some types of castings, however, where such properties are not required, alloys of this type are, however, quite satisfactory. For example, in the case of the production of very thin castings, such as plumbers' ferrules and other similar work, it is desirable to use metal which will run very thin sections without the chance of misrunning. And an alloy which is admirable for this purpose is aluminium-brass high in zinc. In the oxidation of copper by the addition of zinc, it has been claimed that the zinc is more effective in deoxidising when it is added in the form of brass scrap than as the pure metal. It has been shown that less zinc is required when it is added in the form of brass than when it is added as the pure metal.

Turnings and Borings.

Yellow metal turnings form a considerable bulk of the scrap yellow metals which are handled upon the scrap market. Such materials are liable to be contaminated with aluminium and with manganese, and it is necessary, therefore, to examine them carefully for these two constituents before melting. Turnings and borings may be readily melted in crucibles fired by coke. The crucible is usually filled and covered with about an inch of fine charcoal powder, and heated very rapidly so as to avoid excessive loss by oxidation, which might result by slow melting. If this material is melted rapidly and properly a clear bath of metal will be obtained beneath the charcoal layer, and there will be no pasty material in evidence. Further amounts of turnings or borings may then be added so long as they are dissolved in the molten bath without causing solidification of the matter. In order to remove any small amount of aluminium up to about 0·2% it is desirable to add in, for example, about 5% of copper oxide with the charge prior to melting. Alloy obtained in this way and ingotted is first-class material for a great variety of purposes. The melting loss on such material thould not be in excess of 5%. Although the analysis of ingot contained by the melting of turnings varies enormously according to the nature of the material being dealt with, a typical analysis of turnings from red brass will run somewhat as follows :—Tin 7, lead 2, iron 0·2, phosphorus 0·3, zinc 4·8, copper remainder.

The melting of brass turnings and borings has long been a considerable industry in all countries. At one time the bulk of the ingots made by this process were used for the production of sand castings for cabinet brass foundry and other similar material. This small brass-founding industry is, however, at the present day tending to be displaced to a considerable extent by hot brass pressings. Hot brass pressings are obviously preferable to castings for many purposes, since they are closer in grain, less porous, and stronger in mechanical properties than castings can possibly be. In the Birmingham district of England this industry is now almost at a standstill. This is on account of the intrusion of the hot brass pressing field into the casting industry. A large proportion of turnings and borings from brass and bronze bars result from the machine shop making repetition pieces by capstan lathes. The machinist generally uses for this purpose bars of brass and similar alloys which are very free cutting. The swarf from such material is usually bought back by the producers of extruded brass bars at a price higher than can be paid by the independent brass borings smelter. These larger firms who do the extruding themselves usually remelt borings and turnings in large reverberatory furnaces in charges of ten tons or more at a time; they maintain the metal molten while analysis is proceeding, and make the necessary additions to bring up the charge to any desired composition without ingotting intermediately.

Brass Stampings.

A considerable amount of brass stampings or skeleton brass is constantly passing into the scrap metal market. Such material needs to be briquetted or baled in order to make it suitable for crucible melting, or even to make it suitable for melting in large reverberatory furnaces, it is desirable to compress it into blocks. It is often worth while to anneal such material prior to baling in order to make it more malleable.

Soft brass scrap, of this kind, however, will bale quite satisfactorily without annealing. Brass of this kind is usually of the highest grade, generally running about 70% copper and 30% zinc. Such material may contain lead, but in such case it will never be present to an extent more than about 2·25%. The presence of lead in ingots made from such metal as stampings may be detected by the fact that if lead is present the chips which come up from the drill will be short and brittle, whereas if lead is absent they will be long and curly. The copper is usually high in such stamping material since it is very difficult to roll and work alloy containing less than 60% of copper. Scrap brass tubing is usually composed of about 70 : 30 composition, it is sometimes nickel plated, but this does not matter, since the coating of nickel is so thin. In melting tubing it is often advisable to add a tablespoonful of salt, common salt, per 20 lb. of metal, since this prevents to some extent

excessive melting loss. The addition of salt in this way is also often desirable in the melting of chippings and turnings and borings as earlier described. The composition of ingots made from free-cutting screwing rods is generally about copper 62-70, lead 2·5, zinc the remainder. In heating castings from scrap metal it is desirable to heat the metal if it is made, for example, from borings or tube scrap to a point at which the green zinc flare is just perceptible on stirring and prior to pouring. When pouring the castings it is essential to keep the runners entirely full of molten metal so as to prevent the access of air to the mould with the formation of oxide which is liable to give streaks upon the castings and otherwise dirty surfaces. When thin small castings are to be made it is necessary to heat the metal to a point at which it will flare very strongly when the surface is exposed by pushing aside the charcoal cover. In the case of heavy large castings, however, it is desirable to pour as cool as possible and there should be no flare discernible upon the surface of the metal to be used for such castings. When, as in this case, the temperature is to be maintained a little lower than for thin castings, it is desirable to pour a little more strongly so as to counteract the possibility of getting misruns or air-blocks in the castings.

Miscellaneous Scrap Brass.

Cast cocks and faucets occur on the scrap metal market to some extent. Cocks and faucets are generally either of red or of yellow brass; typical analysis of red brass from faucets runs: Copper 83-88%, zinc 5-10%, lead 4%, tin 2-4%. Yellow brass from faucets generally runs about 27-30% of zinc, with about 5% lead and remainder copper. Beer cocks are generally high in lead content and so must be segregated and melted together, otherwise good brass mixtures will be spoilt by the addition of beer faucets, generally speaking. Gas taps are generally made of ordinary yellow brass fairly high in zinc. Thin light brass scrap may often contain and generally does contain considerable amounts of impurities in the form of iron, nickel, such as nickel plating, solder, etc. It is not easy to remove the iron by magneting and by hand picking, so that it is generally necessary to resort to melting in order to get out the iron. The iron in the form of wire strips, etc., will often float on the surface of the molten brass and from there it can be skimmed off. A certain amount of iron, etc., dissolves in the brass and presents more or less of a problem. So long as the iron is actually dissolved in the brass it does not offer any particular disadvantages; in fact, it stiffens up the brass and hardens it to some extent, but when iron is present in large amounts dissolved in the brass it tends to precipitate at the grain boundaries in the form of minute particles which tend to blunt the machinist's tools and render machining difficult. It is therefore preferable to use brass of this kind for castings which do not have to be machined very much. The melting loss on light thin brass scrap is rather high and may often amount to 20%, this loss being partly accounted for by the extraneous materials mixed with the actual brass metal itself. It is of course, desirable to separate as carefully as possible any scrap of considerable size which can be recognised—that is to say, the composition of which can be deduced from the form in which the materials were cast or manufactured. For example the framework of clocks is generally a copper-zinc alloy containing about 65% copper, 35% zinc, and 2 or 3% of lead, while brass used for steam connections—cocks, unions, etc.,—generally analyses:—Copper 85%, tin 5%, lead 5%, and zinc 5%. Often after careful separation has been made in the sorting department, it is usual to treat very light scrap brass in the melting and refining process to obtain the copper content only. According to this process the zinc is all volatilised, iron and other impurities are removed in the slag and only copper is reclaimed. Such brass scrap is only treated in this way when the proportion of iron and other extraneous impurities are so high that it is impossible commercially to separate them by hand picking, magneting, sorting, etc.

The disadvantage, of course, of melting brass scrap of this kind in the ordinary way in crucibles when it contains high iron, is that the castings which are made from the brass obtained in this way are generally of rather poor grade. The iron which inevitably dissolves to a certain extent in the brass makes the brass castings scaly and a dark colour of dirty appearance. The addition of copper-oxide to brass which contains iron will remove a considerable percentage of the latter, even up to about 10%; this is possible on account of the oxidation of the iron by the copper-oxide; it is not, however, possible to remove the last traces of iron by this process. Furthermore, brass which has been treated with copper-oxide to remove the iron should be ingotted and then remelted under charcoal, and deoxidised with phosphorus before it is used for making sand castings. The presence of iron in molten brass can often be detected by the fact that a thin black scum and little blisters form on the surface of the metal after skimming. These blisters rise to the surface, coalesce, and form a skin quickly again after each successive skimming operation. Actually continual skimming for a considerable period would in this way remove the bulk of the iron from the brass in the form of the scum, but such practice would be tedious and not commercially possible.

A certain amount of brass is inevitably removed in the skimmings and so would be wasted. In cases where iron is present in the brass, and it is not possible to remove it for some reason or another, it may be desirable to get it taken as fully as possible into solution in the brass; this may be accomplished to some extent by the addition of a mixture of sodium carbonate and ordinary silica sand. About 3% of a mixture of equal parts of these substances may be added to half of the melting charge at the commencement of the melting operation and the remaining half may be added when the charge is completely molten. This should be stirred in with a graphite stick and then followed by a small percentage of phosphor copper—for example, 1 oz. of phosphor copper per 100 lb. of alloy. From these notes it must not be inferred that iron is always detrimental in brass mixtures, because it is added intentionally in some cases—for example, in manganese-bronze to give added strength and toughness. It is also used in aluminium-bronze to a considerable extent as an important alloying element. Another form of brass residues which appears upon the market is emery grindings. These, as the name implies, result from the grinding of castings in the foundries. This material melts quite readily in the crucible, and was at one time used extensively for the production of saddlery hardware and plumbers' ferrules. These castings were poured very hot in order to get them to run completely. It is more general nowadays, however, for these purposes to use some such alloy as copper 54%, zinc 40%, lead 5%, with a little aluminium in order to increase the fluidity of the metal.

The Influence of Various Elements in Brass.

It is interesting finally to review the influence of one or two other elements than those already described upon the properties of brass.

Magnesium.

Magnesium makes brass rather black-coloured when it is poured into the form of castings, the magnesium also causes oxide foldings and reduces the fluidity of the metal so that with even as small an amount as $\frac{1}{4}$% even the simplest castings cannot be satisfactorily run. Brass never contains magnesium unless added accidentally or in the most minute quantities. When magnesium is added to brass, however, it is general to employ a 10% magnesium copper alloy as a hardener.

Silicon.

Silicon is used to some extent for the deoxidation of copper and copper alloys. It is fairly satisfactory as a deoxidiser for copper but should not be used in brass or

bronze because there is generally lead present in the latter alloys with which the silicon forms lead silicate, and this tends to produce drossy slag upon the surface of castings and to cause the metal to be sluggish and run badly into the mould. Silicon should be added in very small amounts to copper, and the silicon should be free of all other elements —for example, particularly aluminium. Unfortunately, the addition of silicon is not possible to copper which has to be used for electrical purposes, since the electric conductivity is reduced by about 50% by the addition of the smallest trace of silicon. It has been stated that a mixture of copper-oxide with sodium-chloride will remove silicon from copper, but whether this is so or not does not appear to have been definitely established. The effect of antimony in brass is to cause embrittlement. Even 1% or less of antimony renders brass castings entirely brittle and useless.

Aluminium.

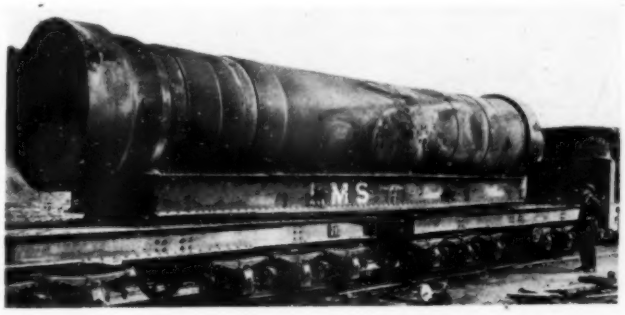
Considerable work has been done upon the determination of the influence of aluminium upon the properties of brass, and although at one time aluminium was thought to be definitely deleterious in brass for all purposes, recent work has shown that the addition of small percentages definitely improves certain properties of brass and renders the material more suitable for some purposes—for example, the resistance to corrosion of condensor tubes is considerably improved by the addition of 1% of aluminium. For a long time aluminium has been added to high-zinc brass in order to increase its fluidity, and also to lessen the zinc fume when the metal is poured. It is surprising what an effect upon the surface appearance of ingots even a very small proportion of aluminium will exert. The surface of ingots which are normally of a rough dark brown khaki or chocolate colour when aluminium is absent is converted to a smooth golden silvery appearance when there is only as little as 0·5% of aluminium present. For some purposes this has been considered very objectionable, and considerable effort has been directed to means for removal of these last traces of aluminium from such alloys. It appears that copper oxide added to ordinary tin bronze will remove aluminium in small amounts from it, but that copper oxide will not remove aluminium from ordinary brass. Certain patented fluxes have, however, from time to time been recommended for the removal of aluminium from bronze.

(To be continued.)

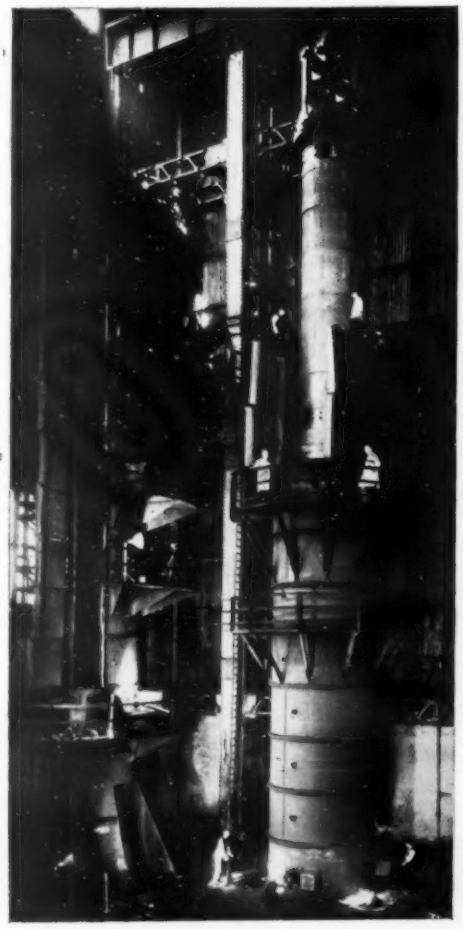
Forgings for the New Coal Hydrogenation Plant

THE development of chemical and oil engineering processes has increased the demand for large, hollow, forged-steel pressure vessels, and complex investigations have been necessary to determine correct methods of design and the most suitable materials. The large size of the forgings required is sufficient in itself to make the production of such vessels a matter of note from the engineering point of view, and the manufacture of the huge forgings for the coal-hydrogenation plant being erected by the I.C.I., Ltd., at Billingham, is particularly noteworthy.

The largest hollow forgings, the converter bodies, which are approximately 35 ft. long, 6 ft. 6 in. maximum diameter, and, in the rough-machined state, weigh about 80 tons, undergo heat-treatment in vertically gas-fired furnaces before being finished machined. This treatment involves oil hardening and tempering, and it is doubtful whether such an operation ever before has been attempted in this country on such a large mass of material. In an accompanying illustration a converter body is shown being lowered by means of an overhead 130-ton crane into a vertical gas-fired furnace, the top two doors of which are open. The huge dimensions of this furnace will be realised.



Heat-treated forging being transported to machine shop on special truck.



Heat-treating forging for converter body.

The other illustration shows the forging, after heat-treatment, being conveyed to the machine shops on the special type of wagon necessary when dealing with such heavy weights. The photographs were taken at the Vickers Works of The English Steel Corporation, Ltd., at Sheffield, where these large forgings are manufactured.

Correspondence

Practical Handling of Copper Wire Scrap.

The EDITOR, METALLURGIA.

Sir,—With reference to a contribution which appeared in your June issue under the title of "The Classification, Properties, and Utilisation of Non-Ferrous Scrap Metals and Alloys," I beg leave to refute some of the statements. I do not wish to criticise the author, but all practical metallurgists who have been engaged in this line recognise the uselessness of crucibles for this work.

A common misconception appears to exist in some quarters that copper wire scrap may be economically melted in crucible furnaces. It has been repeatedly proved that in actual practice such conditions do not obtain. No point is gained by use of the crucible in this connection, and incidentally all impurities present in the scrapped material are retained in the ultimate product. On the one hand, copper wire scrap which has accumulated in heaps literally acts in the capacity of a dust collector, and hence could scarcely be expected to be free from deleterious material. On the other hand, wire which is covered with insulating material in the form of different fabrics requires to have this latter removed so that the copper can be recovered. The customary method is simply to burn off as much of the insulating material as possible. In so doing, however, any sulphurous material is liable to be partly absorbed by the copper. To suggest melting this wire in the crucible means that sulphur will exist in the product, which is one of the most undesirable impurities conceivable. No scope is offered for refining in the limited space of the crucible.

The only case which might be cited in favour of the crucible is in some odd engineering shop where it is desired to acquire a small amount of melted-down copper. So far as regular metallurgical practice is concerned, the practice is most uneconomical, for the following reasons:

The copper retains all impurities from associated waste material, or from the burnt-off insulating material. The limited space has to be supplied with the full heat for a small charge. As the crucible is largely occupied by space until all wire in bundled condition has reached the melting point, this means that full working temperatures and full fuel costs require to be maintained to no purpose. What copper is melted first remains in the bottom of the pot, absorbing further heat. Other classes of furnaces which are simply intended to melt the mass, ensure it being tapped without delay, so that no such unnecessary heat-absorption takes place. For crucible purposes, copper wire scrap has not merely to be bundled, but also to be cut up to suit the limited size of the pot. Anyone with practical experience of scrap handling knows what this means, since bundled wire depends on the bundling to keep the tangled mass rigid. Once this has been cut up, small sections of wire are allowed to loosen and fall out.

Practical Melting.

Efforts at melting-up copper wire scrap in the electric-resistance furnace have been abandoned for the same reasons as obtain with the crucible furnace. It is known that the cupola was tried for this work, and also abandoned, but the conditions here were different. The actual melting was economical, but the losses of copper sustained by volatilisation were much higher than anticipated, and of course no means were available for refining the product.

There is nothing original about the use of the reverberatory furnace for melting different classes of wire scrap, but to-day the best refining methods are applied. This method has the following advantages: The fuel and working costs are low. A considerable charge can be worked at a time. All impurities present either as a result of dust and dirt picked up by the scrap wire, or from the insulating material, are removed by the usual copper refining methods. Large bundled blocks of wire are charged which remain rigid, and no cutting of the blocks is necessary whereby the wire can loosen out from the mass. The construction of the reverberatory furnace hearth makes due allowance for space, and unlike the crucible furnace makes full use of the heat applied. When desired the mass of melted wire may be tapped off directly, and not refined as is done in the crucible furnace. Where refining proper is employed, all kinds of fluxes may be charged, whereas the pre-heater or "deepener" used above the crucible limits this application.

The reverberatory practice embraces melting the wire scrap and refining by a series of oxidising and reducing influences which are introduced under ideal conditions. Full advantage is taken of the copper scale present on the surface of the wire. This is augmented by the oxidised skin which forms as a result of the hot furnace gases impinging on the wire on the sloping hearth, and is of great value for oxidising impurities in copper. It is not that the copper of the wire need come in for scrutiny, but the metallic particles retained by the open nature of loose bundles of wire and sulphur, as in the case of cable which has been subjected to preliminary burning. Probably the only instance where copper wire is utilised in crucible furnaces is in the making up of copper alloys, but as a means of refining the scrap it has no practical value.

June 28th, 1934. A. G. AREND.
Glasgow, C. 2.

The Editor, METALLURGIA.

Sir,—I consider that the information contained in Mr. Arend's letter is supplementary to, rather than contradictory of, my article on "The Classification of Non-ferrous Scrap Metals, etc."

In my article I have merely offered some data from my experience *of the use of different kinds of copper-bearing materials by the small foundry*. I do not attempt to describe the reverberatory refining methods, of which, of course, I am quite aware, but which are only employed for treating relatively large bulks, and by firms who can afford the necessary equipment. The small foundryman certainly cannot, nor would he have the necessary technique for processing the scrap.

The small foundries buy all sorts of scrap and make it up into their alloys for casting direct, as brass, bronze, etc., and they almost always melt in what is for them the most convenient form of furnace, namely, the crucible furnace. It is to them I was addressing my remarks on *melting*, and not to the large refining firms. In any case, I devoted a small space only to the question of melting, for the very reason that that was a matter which could well be left to the foundryman, but that information as to the snags to be run into in the purchase of odd lots of alloys was where he needed advice.

Some of the points Mr. Arend makes as a criticism of my paper, and as lacking from it, are there if he will read it again more carefully, for example, I have advised furnace refining of "burnt-off" wire on p. 48 (nineteenth line down, left), and warned against sulphur getting into the metal (p. 47, bottom, right).

With reference to *baling*, I had in mind the use of bales to fit the crucible, a matter easily arranged when purchasing the machine or the crucibles. I never suggested anything so foolish as cutting bales.

I contend that baled annealed wire makes a very convenient melting charge for the foundrymen—given care in melting.

And as to the criticism of crucibles altogether as a melting medium for this class of work, it can only be inferred that Mr. Arend and myself are at cross-purposes in the discussion, because of all furnaces none is more popular among small users than the crucible furnace, and the writer has made up many thousands of tons of alloys of the very highest possible grade by such means.—Yours, etc.

SPECIAL CONTRIBUTOR.

Warwickshire.

Notes on the Metallography of Light Metal Alloys*

By A. Blumenthal, Jena.

Metallography, as is well known, deals with the constitution of metals and alloys and their relation to the physical, mechanical and chemical properties; it is obvious, therefore, that the characteristic details of the microstructure of metal and alloys should be presented in the most suitable form to facilitate their study. In this article, the author describes the technique employed in the metallographic investigation of some light metal alloys.

Fig. 1. 10 : 1.

Fig. 2. 50 : 1.

Silumin, etched with 0·5% hydrofluoric acid.
Al Dendritic structure in irregularly-distributed Al-Si eutectic. Dark brown, in part bluish, needles plainly consisting of a ferrous type of crystal.

THE purpose of the following notes is to render available to a wider circle the experience which we have gained in a special branch of metallography. No claim is made that they are fundamentally new, or complete; they are intended only as a contribution to a subject upon which but little has yet been published. For convenience, the technique is described under two headings.

Aluminium Cast Alloys.

In preparing specimens of aluminium alloys, it is particularly important, on account of their softness and readiness to oxidise, to use care in grinding, and to avoid the use of water in polishing and cleaning off. We have found the following method satisfactory: Grinding is done entirely by hand, on dry, worked-down emery paper of grades 1 G, 1 M, 1 F, 00, 000. The final grinding is on worked-down 4/0 paper, moistened with a little petroleum. It has proved expedient to moisten all the emery papers with petroleum, since grinding with too much petroleum causes the surface to become badly roughened. As with other metal sections, we have found preliminary polishing advisable also with aluminium alloys. The preliminary polishing is done on a horizontal disc covered with stretched felt, revolving at a speed not greater than 200 r.p.m. The polishing agent is fine, 60-minute washed emery, which, in the case of aluminium alloys, is worked up to a cream with alcohol or methylated spirit. The preliminary polishing greatly facilitates the subsequent fine polishing. Care should, however, be taken to polish lightly, and very wet, with only a little emery, as otherwise the surface will be roughened. After careful cleaning off, using, as already mentioned, only spirit, the specimen is fine-polished in the usual manner. We use discs revolving at about 1,000 r.p.m., over which is stretched special polishing cloth for aluminium alloys. The finest alumina is used for polishing, mixed with spirit. As regards the time of polishing, it seems true in this case that the longer polishing is carried on, the finer does the polish become, so that it is simply a matter of the time available. In polishing, alumina and spirit must not be stinted, so that the cloth and specimen are always very wet.

Etching must follow as quickly as possible after polishing, otherwise the specimens tarnish, and so prevent a clear etching from being obtained. We made experiments with 0·5% aqueous solutions of hydrofluoric acid and cold saturated caustic soda. It proved to be quite generally true that hydrofluoric acid etches much more cleanly than caustic soda. Further-

* Translated from *Zeiss Nachrichten*, April, 1934, pp. 28-34.

Fig. 3. 15 : 1.

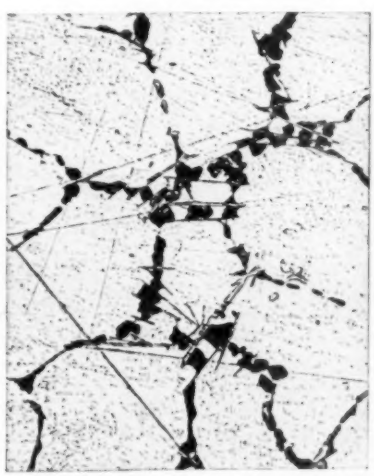


Fig. 4. 200 : 1.

American alloy: 8% Cu, the remainder Al.
Etched with 0·5% hydrofluoric acid. Separated Al-Cu mixed crystals with $CuAl_2$ eutectic in the interspaces.
Etched with cold saturated caustic soda. $CuAl_2$ eutectic network with fine, light grey needles, obviously of siliceous type.

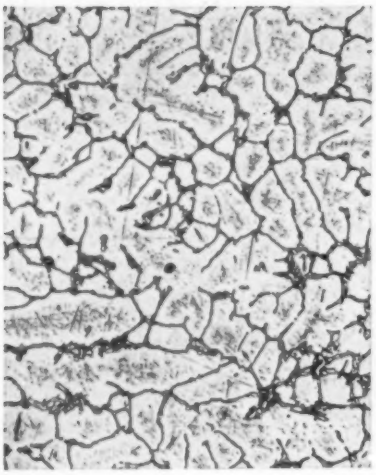


Fig. 5. 50 : 1.

Fig. 6. 200 : 1.

Alloy: 5·5% Cu, 7% Sn, the remainder Al, etched with 0·5% hydrofluoric acid. Separated ground mass with $CuAl_2$ eutectic network. Between the eutectic angular, distinctly yellow structural elements, roughened after etching.

more, hydrofluoric acid appears generally to show up crystalline separations, and scarcely colours the components, whilst bringing their outlines into sharp relief, whereas etching with caustic soda colours them differently, but does not outline them so sharply. (Compare, for example, the Cu-Al_2 network in Figs. 4 and 6.)

Figs. 1 to 8 shows some photomicrographs of different aluminium cast alloys. Composition, etching, and, as far as possible, structure are given beneath the illustrations. It is, however, not our task here exhaustively to describe and explain the occurrence of different kinds of structures and the different appearances they present. Our principal object is to contribute to the technique of metallographic investigation.

Electron Die Casting, Alloy A.Z. 91.

The polished specimen is prepared in the same manner as already described for aluminium alloys; the samples are carefully polished by hand on worked-down, dry emery paper. Grinding with petroleum has proved unsuitable in this case, as also has preliminary polishing, which produces too great a relief with these alloys. After fine-grinding with 4/0 emery paper, and cleaning off with alcohol, polishing is done as before with finest alumina mixed with alcohol. Electron polishes fairly quickly, because, although it is soft, it is not very tough. It is not advisable to polish too long, because the material tends strongly to polish up in relief. The specimen is at first held against the disc with moderate pressure, and finally very lightly polished. With electron it is particularly important to keep the cloth and specimen very wet. If polishing is done too dry the specimen at once becomes badly oxidised. For cleaning off, only alcohol or spirit must, of course, be used.

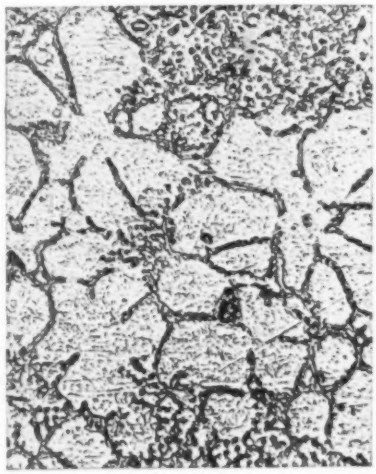


Fig. 9. 200 : 1.

Fig. 10. 200 : 1.

Electron die-casting: 9% Al, 1% Zn, some Mn, remainder Mg, etched with aqueous dilute sulphuric acid.

Sample from the feeding head. *Sample from narrow cross-section of casting.*

Al-Mg mixed crystals in eutectic of mixed crystal and Al_2Mg_3.

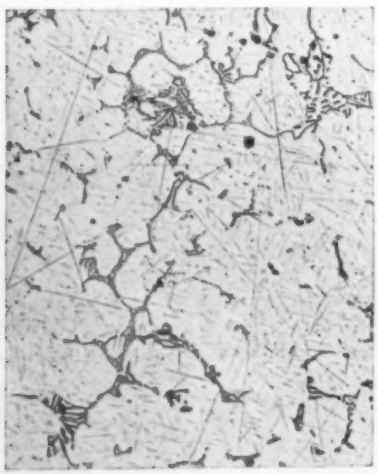


Fig. 7. 50 :1.

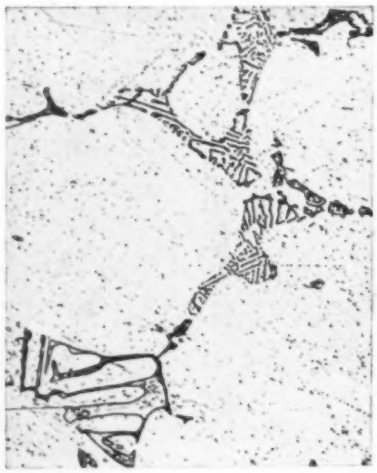


Fig. 8. 200 : 1.

K S sea-water alloy, etched with 0·5% hydrofluoric acid. Various eutectics of $MnAl_2$, Mg_2Si and other compounds. (Fig. 8 shows the left-hand bottom corner of Fig. 7.)

For etching we used dilute sulphuric acid, at a concentration of five drops of concentrated sulphuric acid to 100 c.c. distilled water. The time of etching was about eight seconds.

Figs. 9 to 12 show some photomicrographs of die-cast electron, Figs. 9 and 10 showing the structure as cast. The sample of Fig. 9 was taken from the feeder head, and had a greater cross-section than the sample of Fig. 10. The structure shows the Al-Mg mixed crystal in the eutectic of mixed crystal and Al_2Mg_3. In conjunction with the I.G. Farben,, Bitterfield, attempts were made to homogenise by annealing and quenching. Annealing below the transformation temperature appears to give rise to processes similar to those of, for example, the annealing of steel. Some samples which had obviously been annealed at too low a temperature thus showed, after quenching, a structure very

similar to that of grained pearlite. Further, as can be seen from Fig. 11, with electron also the incompletely-dissolved chemical compound appears to separate at the crystal boundaries. Finally, Fig. 12 shows a structure which occurred in samples that were slowly cooled after annealing, and only quenched from low temperatures.

[All the photographs reproduced in this article were taken with Zeiss metallographic microscopes, using Zeiss objectives and eye-pieces.—ED.]

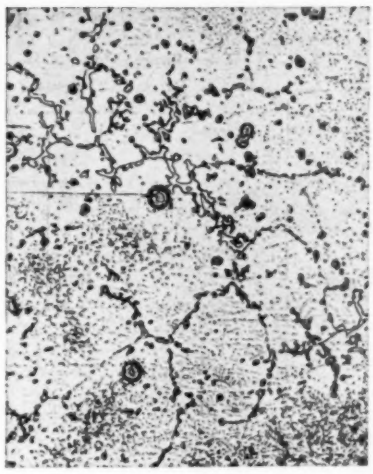


Fig. 11. 200 : 1.

Annealed 12 *hours at about* 380°, *and quenched with compressed air ; Al-Mg mixed crystals with residues of* Al_2Mg_3 *at the crystal boundaries.*

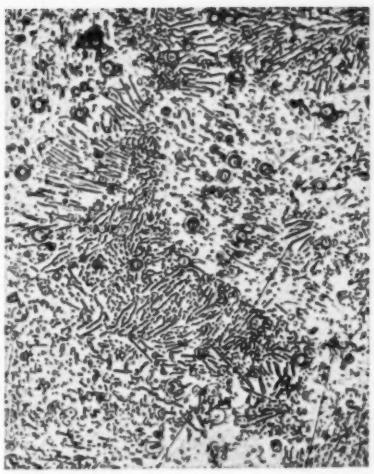


Fig. 12. 500 : 1.

Annealed 24 *hours at about* 380°, *cooled off in the furnace to about* 250°, *then quenched with compressed air.* Al_2Mg_3 *separated into bands.*

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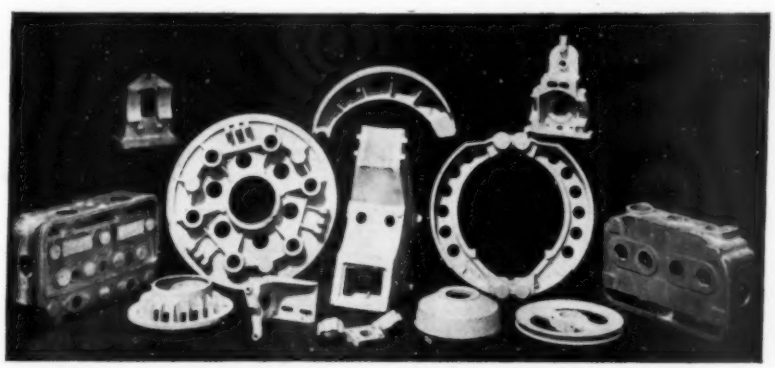
New Light Metal Alloys

In this article brief reference is made to two recent developments in the light alloy field.

PROGRESS in the development of light alloys is continuous, and of recent additions in this field the new light aluminium alloy developed by Messrs. J. Stone & Co., Ltd., of Deptford, is noteworthy. It is marketed under the name of Ceralumin "C" and it has been developed to meet the demand for an alloy of low-specific gravity and high strength, combined with good casting properties. The composition of the alloy, which is covered by British Patent No. 403,700, is as follows:—

	%
Copper	2·5
Nickel	1·5
Magnesium	0·8
Iron	1·2
Silicon	1·2
Cerium	0·15
Aluminium	remainder



An assortment of castings in Ceralumin "C"

From this it will be seen that Ceralumin "C" is a complex alloy of aluminium, the most novel feature being the presence of cerium. Investigations in the Company's laboratories have established the fact that, in addition to its refining action on the macrostructure, cerium allows the beneficial mechanical effects of a high-iron content to be obtained by suppressing the embrittling iron-aluminium constituent which is otherwise liable to be formed. In addition the small amount of cerium also confers on the alloy important advantages in the foundry. Ceralumin "C" has extremely good "running" properties, and gives castings having a smooth, clean surface and an attractive appearance.

The heat-treatment applicable to this alloy is quite simple. The castings are maintained at the solution temperature of 515° to 535° C. for 4–6 hours and then quenched in water ; ageing is achieved by heating to 175° C. for 16 hours, followed by quenching in water. The risk of distortion at the solution temperature is no greater than that involved, for example, in heat-treating "Y" alloy at 520° C., and careful measurements on castings having unfavourable features, such as overhung arms and bosses, have failed to detect any distortion as the result of heat-treatment.

In the heat-treated condition Ceralumin "C" presents an excellent combination of high-tensile strength at ordinary and elevated temperatures, high-elastic limit and high-Brinell hardness. These features are given in detail in the table, but special attention must be drawn to the very high fatigue strength (Wöhler, 20 million reversals) of +8.25 tons per sq. in., a quality which should prove of special interest to designers anxious to take the fullest advantage of the properties of available materials.

Ceralumin "C" is suitable for high-duty service in the form of die-castings, chill castings, and sand castings, and it is anticipated that it will find a useful field of application, particularly in the aeronautical and automobile industries.

If the artificial ageing treatment is replaced by ageing at room temperature for five days, a modified form of the alloy is produced which is called Ceralumin "D." By this means a somewhat lower tensile strength is obtained, but the ductility is considerably increased. This modification of Ceralumin "C" is intended for purposes where extra

toughness is required in castings, such as for shrinking-on cylinder heads, where heavy stresses may be set up and a little "give" in the casting is essential.

	0·1% Proof Stress, Tons/sq. in.	Maximum Stress, Tons/sq. in.	Elongation %	Brinell Hardness Number.
CHILL CAST—				
Fully heat-treated ..	21–24	23–27	1·0	130–140
Quenched and aged five days at room temperature	13–14	19–21	4–6	98–104
No heat-treatment ..	11–12	13–14	1–3	67–77
SAND CAST—				
Fully heat-treated ..	18–20	19–20	0–1	130–140
Quenched and aged five days at room temperature	11–13	14–16	1–3	98–104
No heat-treatment ..	—	8·5	0–1	72

Aluminium-clad Duralumin.

ANOTHER development is the recent production of a material known as "Aldural" by James Booth & Co., Ltd. It has been produced in order to meet the demand for a material having all the characteristics of "Vickers' Duralumin," but possessing, at the same time, a greater resistance to the more severe types of corrosive agents. "Aldural" can only be produced in the form of rolled metal, and consists of a coating of aluminium of the highest degree of purity on each side of the rolled Duralumin. The coating on each face is about 5% of the thickness of the core.

It is generally appreciated that Duralumin as normally supplied offers a strong resistance to the corrosive effect of ordinary atmospheres, being in this respect much more resistant to corrosion than iron and steel. For a great many purposes, and in places where it is not exposed to marine conditions, Duralumin may be used with entirely satisfactory results, and, if suitably protected, either by painting, varnishing, or by anodic oxidation, it functions without deterioration for years, even under quite searching conditions.

Under sea-going conditions the severity of the attack is such that it is essential for the material under such protective coating to be resistant to corrosion to the greatest extent possible, and this is particularly true of built-up and riveted structures. If ordinary Duralumin is used in such circumstances, the measures required for protection are necessarily severe, and anodic oxidation is quite essential. With "Aldural" the resistance is so good that this expensive operation is usually unnecessary, and painting or varnishing is also obviated. If the conditions are so onerous that it is considered desirable still to protect either with paint or by anodising, the "Aldural" is still very superior, because if the paint or varnish is chipped away, or the anodic film destroyed, the aluminium coating on the "Aldural" still persists and protects the alloy in the core. Furthermore, this coating has a very protective effect upon the alloy rivets used in jointing-up the structure.

This aluminium-clad Duralumin has a strength but little inferior to that of Duralumin, as would be expected from its construction, and its ductility is quite as good. The working and heat-treatment demand the same technique as Duralumin; but, in general, it will be found that, owing to the extremely ductile outer skin, forming operations can be carried out more easily than with the uncoated alloy. If it is desired to re-heat-treat the alloy great care should be exercised, especially in the thinner gauges. The time of exposure to the heat-treatment temperatures should be kept at a minimum. Undue soaking will tend to reduce the corrosion resistance of the coating.

Some idea of the resistance to corrosion offered by this new material may be obtained from the following test figures, which show the effect upon the properties of unprotected "Aldural" of an intermittent salt spray in an accelerated corrosion test. It should be observed that such corrosion tests are much more severe in their effects than are the worst service conditions.

Time of Exposure.	0·1% Proof Stress Tons/sq. in.	Maximum Stress Tons/sq. in.	Elongation %
0 days	17·20	25·30	18·0
50 ,,	17·00	25·10	17·0
100 ,,	17·10	25·10	18·0
150 ,,	16·90	25·20	17·5

Further experiments, carried out on specimens exposed to high- and low-tide conditions in the North Sea, show that there is no diminution in mechanical properties after one year's exposure.

The mechanical properties of "Aldural" may be taken to be as follows:—

Proof stress (0·1%) tons per sq. in., not less than 13·5
Maximum stress (0·1%) tons per sq. in., not less than 24·0
Elongation, % (16 S.W.G.), not less than ..... 15·0

Testing of Thin Metal Sheet and Strip.

The British Standards Institution have just published a new issue of B.S.S. No. 485, which supersedes B.S.S. No. 485 Part I, which was issued last year. This specification has been amplified by the addition of three new sections which deal with bend, hardness and cupping tests respectively.

Bend tests have been classed under two main headings, "single bends" and "reverse bends," and the different forms of these have been dealt with separately in detail. The section on hardness testing outlines the factors to be taken into account when Brinell and the Diamond Pyramid hardness tests are carried out on thin sheet metal. It has not been possible to lay down any standard form of cupping test, but an interesting note has been included pointing out the extent to which such tests may be of value for routine work.

Two important modifications have been made to the section previously issued covering tensile tests. One is the extension of the scope. It has been brought into line with the new sections so that the whole of the new specification covers material up to 10 S.W.G. thick. The other modification is the inclusion of a statement that in the case of strip material which is too narrow to provide a tensile test-piece of the standard form, the material shall be tested the full width as rolled, but attention is called to certain necessary precautions which must be taken if values other than the tensile strength are required.

The amplified specification which now deals with all the usual forms of mechanical tests on thin sheet and strip material should be extremely valuable, particularly to testing departments and those sections of industry interested in the production and use of sheet and strip material.

Copies of this revised specification (B.S.S. No. 485–1934) may be obtained from the Publications Department, British Standards Institution, 28, Victoria Street, S.W. 1. Price 2s. 2d. post free.

Tests on tramway rails, recently made in France, showed that rails of nickel-chromium steel gave superior wear-resistance as compared with rails of manganese steel and 2% chromium steel. It is of interest to recall similar tests which were made in 1919 by the Milwaukee Electric Railway Co., using an air-hardening cast steel containing 0·5% carbon, 2·8% nickel and 0·8% chromium. It was found that the degree of wear observed in manganese steel crossings after 160,000 cars had passed over them was reached only after 278,000 cars had passed over the nickel-chromium steel crossings.

Reviews of Current Literature.

The Hardness of Metals and its Measurement.

THE metallurgist and engineer cannot ignore the working aspects of materials used because, in practice, these materials have to be handled with all the uncertainties that are inseparable from their behaviour, and this involves different kinds of stress and their effect in strain. Thus, to the engineer, in particular, the physical properties of materials are of very high importance because the forces acting upon a mechanism would destroy it by distortion or fracture if the strength did not correspond with the particular stress imposed. While it is necessary to know the nature, direction, and the intensity of the forces acting upon every element in a mechanism, the capacity of the material to resist these forces without distortion or fracture is of primary importance. It is for this reason many and varied tests are applied to materials in order to determine their relative resistance to forces so that when the amount and distribution of the stress in an element is known its resistance can be calculated.

Among the properties of metals and alloys which are significant few, if any, exceed that of hardness in importance; yet this property is very indefinite and no satisfactory definition of it has been given. In this work the author makes no attempt to define the property, because no single definition can apply. The investigation of this property, which is so difficult to express, is complex, and a great deal of work has been carried out in an effort to devise means for determining the relative degree of hardness of materials. According to H. Le Chatelieu, the problem seems to be to establish two or three methods of reference for hardness, giving as widely different results as possible, so that hardness may be studied under all its phases. Afterwards, for each particular application, the reference method which is most applicable to the conditions may be used.

The problem presents so many aspects that it would not be surprising had it failed to yield anything of real utility. The very reverse, however, is the case. In the realms of hardness practice has outstripped theory, and the various technical hardness tests have been of the greatest value to industry for judging and controlling the quality of metallic products. Considerable data have accumulated in connection with such tests over a period of more than thirty years, and in this work the author has co-ordinated much of this scattered information. For this purpose hardness has been interpreted in the widest sense, and, consequently, observations are included on the deformation of metals by tension and compression, for example, as well as by indentation.

The problem of hardness is discussed in a very thoughtful introductory essay, in which reference is made to various older ideas regarding hardness, but the author does not answer the question, What is hardness ? In the first chapter he proceeds to a detailed consideration of the various methods which have assisted in building-up the hardness-testing edifice, and follows this with a consideration of the static ball test. In these two chapters the static indentation test is considered academically, but in the next chapter typical apparatus for static and dynamic indentation tests is discussed, and short descriptions of popular machines are given.

In succeeding chapters the aspects discussed include hardness and its relation to deformation and strain-hardening ; the crystallinity of metals and its bearing upon hardness, in which the development of the sclerometer is considered ; alloying and heat-treatment as related to hardness ; dynamic tests of soft metals and hot metals ; the hardness test specimen, its preparation and examination ; and a final chapter dealing with abrasion, machinability, and cutting hardness.

The subjects discussed in the final chapter are of great industrial importance, yet, despite numerous valuable experiments, our understanding of them is particularly imperfect, although we have been led to appreciate the numerous factors which may be involved. One of these is certainly hardness and another is work-hardening capacity, and the author is to be commended for including the question of abrasion and wear, because any information that will increase our knowledge of the phenomenon of wear is valuable. How useful, for instance, would be a test which gave reliable forecasts of the behaviour of any particular material in service.

That the literature on hardness and hardness testing is enormous is indicated by the bibliography and authors' index in this book. The author has collated 410 references which are quoted in the text, and these are not intended to be exhaustive. In view of the immense amount of work on the subject which has already been published the author is not without courage in preparing this book, but he has rendered a service, in co-ordinating the most important of the information available, that will undoubtedly be appreciated alike by the physicist and the engineer because it combines academical considerations with practice. The book is concise yet comprehensive, and the text and the numerous illustrations are presented in a most acceptable form, for which credit is due both to author and publishers. Finality on the problem of hardness has not been reached, but this is an important contribution to the subject, and is a tribute to the necessity for greater strength being given to the theoretical foundations of the subject.

By HUGH O'NEILL, D.Sc., M.Met., pp. 292 with 119 illustrations. Published by Chapman & Hall, Ltd., 11, Henrietta Street, London, W.C. 2. Price 25s. net.

Carnegie Scholarship Memoirs, Vol. XXII.

IN this book is published further studies of the wire-drawing process. They comprise Parts IV., V., and VIa. ; Part IV. deals with the angle and contour of the die, the investigators being E. L. Francis, M.Sc., and F. C. Thompson, D.Met., M.Sc. Part V. deals with experiments with a rotating die by E. L. Francis, M.Sc., H. Greenwood, M.Sc., and F. C. Thompson, D.Met., M.Sc. Part VIa describes some experiments bearing on the casting of wire, by A. S. Kenneford, M.Sc., and F.C. Thomson D. Met, M.Sc. In each case experiments are described and the results discussed. With regard to the work on the angle and contour of the die, for instance, the authors conclude that, with straight-tapered dies, the best angle for most work is 6°. Deviation from this angle in either direction sets up a greater frictional loss. Where the reduction in the draft is small, however, a smaller angle is necessary, especially with hard materials, in order to obtain the necessary length of bearing. There seems to be justification for the view, however, that the angle even in the latter case should be as near to the one mentioned as possible. On the other hand, when starting with a rough, hot-rolled rod, where the difficulties of really efficient lubrication are considerable, a distinctly steeper angle may at times be required, and the result of this work would be consistent with the view that where this is the case the angle might well be from 10° to 11°. Alternatively, there might, in such a case, be justification for the use of a radial-taper die, giving the necessary high angle of die when the metal first enters, and decreasing to about 6° at the point of exit.

The authors have not yet examined the effect of the parallel portion of the die at the exit end, though there can be little doubt that this will entail the use of a higher tension, against which must be set-off the increased life of the die before it requires resetting. Although this work refers only to tungsten-carbide dies directly, comparison with other work provides no reason to believe that the optimum conditions with a steel die would be appreciably different.

This volume also includes Part II. of the investigations into the nitrogen-hardening of steels by B. Jones, M.Sc., F.I.C., and deals particularly with the nitriding properties of some chromium and austenitic steels at a temperature of 500° C. The investigation is subdivided into two sections. It is shown that many types of commercial steels containing chromium will surface-harden to a value equal to that obtained on case-hardening by carburisation, while the hardness of various steels, containing about 2 to 18% of chromium, is equal to that obtained in the commercial chromium-aluminium nitriding steels. Austenitic manganese steels, containing 10 to 23% of manganese, harden appreciably by the usual method. Chromium-nickel austenitic steels do not harden consistently unless the passive surface film is destroyed. Better results in these steels were obtained by increasing the pressure of the nitriding gases, and a hardness of 1,000 Vickers' Brinell is readily attained in a steel of the 18/8 chromium-nickel type. The effect of copper-plating steels prior to nitriding was investigated, and it was found advantageous in the case of certain steels to carry out the process in the presence of copper. It was found that the absorption of nitrogen in the surface layers of high-chromium steels, and of austenitic nickel-chromium steels, destroyed the corrosion-resisting properties. The magnetic susceptibility of austenitic steels was increased when nitrogen-hardened, due to the effect of nitrogen in causing the γ—α iron inversion in the hardened surface layers.

This book also contains contributions by Dipl. Ing. Wilhelm Kleinefenn, of Aachen, Germany, dealing with an investigation on the metallurgy of the fusion welding of iron with special reference to nickel-alloy welding material, and by Dr. Techn. Tibor Vér, of the University of Technical Sciences, Budapest, which details an investigation on the development of slip lines and fatigue cracks under repeated stresses in low- and high-carbon steels welded by the butt-welding method.

Edited by K. HEADLAM-MORLEY, pp. 156, illustrated. Published by The Iron and Steel Institute, 28, Victoria Street, London, S.W. 1.

Industrial Radiography.

IT is a significant fact that almost immediately after the discovery of X-rays many of the earliest workers anticipated their possibilities in the industrial field. It is well to remember, for instance, that though radiography as a branch of technical activity is still comparatively young, in 1897 Röntgen obtained X-ray illustrations of many metal objects. But the industrial applications of X-rays have undoubtedly lagged greatly behind the medical; this was due to certain factors which militated against their commercial application. The low capacity and erratic operation of the older type of X-ray equipment were, among other things, two of the factors which led to this position. Considerable development has since been effected and to-day X-ray equipment is so safe, simple, and compact that X-ray test and inspection in industry has entered its rightful sphere, and this book has been published at an opportune time.

In view of the extent to which the comfort and even the life of human beings are dependent upon the satisfactory performance of man-made structures and man-made devices, the advent of new methods for determining that material is suitable for service is most welcome. For these structures and devices not only must the physical and chemical properties of the component materials be in accordance with specifications, but also for many classes of service the strictest inspection and test of each part are required. Such tests must, of course, be non-destructive. Herein lies the importance of industrial radiography, for when applicable it is able to assure the designer that the object examined is sound and satisfactory, or to supply evidence as to the location and extent of any necessary reconditioning.

The value of radiography is being increasingly appreciated in the normal routine of manufacture. Its application to foundry practice promises to be one of the most important testing methods employed, and is equally well adapted for ferrous and non-ferrous castings, although greater thicknesses of aluminium can be examined owing to its relatively high transparency. As a matter of fact, by far the majority of large objects radiographed up to the present time have been castings of one kind or another. Whether justified or not, there is a tendency on the part of designing and operating engineers to trust forgings without radiographic inspection. There is no doubt, however, that the method applied to the study of defects in castings, and the correction of the designs of castings to eliminate the possibility of these hidden defects, are making rapid progress, particularly in the production of castings for high-duty service, where failure would entail serious loss and be attended with disastrous consequences. By correlating the nature, amount, and distribution of defects with, for instance, the method of gating or some other important production factor, modifications in design or technique are possible which simplify production, limit the percentage of wasters, increase confidence in the product, and, incidentally, lead to economy in production.

Radiography is particularly applicable to welds, and modern developments in welding, together with the experience gained with large and small pressure vessels, will convince the most sceptical that structures and pressure systems, welded under correct methods, and which X-ray examination shows to be perfect, are eminently safe and desirable.

The present work is intended to furnish in readable form authoritative information concerning the practical use of radiography for industrial service. It presents not only the general principles governing the production and use of X-rays and gamma-rays, but also the special technique suitable for important classes of materials used by industry. To a great extent it represents the actual experience of the authors in the development and use of routine methods for rapid and economical inspection in large-scale commercial operations.

Some of this material, the authors state, is published for the first time. Most of the curves and tables have been adapted from data available in the literature supplemented by private records. Wherever possible they have been expressed in forms immediately useful in the shop. For the convenience of those who may desire to pursue the subject more extensively a bibliography of pertinent literature has been appended. For the sake of brevity and clarity radiographs made with X-rays are frequently referred to as "exographs"; those made with gamma-rays as "gamma-graphs." In many cases the original negative, in which thinner parts are represented by darker areas, has been reproduced. In others a positive print from the negative has been used. In this case, thinner parts are represented by light areas, thus conforming to the usual idea of a shadow picture. Both are encountered in practical operations, and, apparently, it is considered advisable to accustom the reader to recognising and interpreting both with equal facility.

No engineer or practical metallurgist can fail to be interested in this book, because it carries so much information that can be put to use. It is well written, and it is evident that the subject matter is largely the result of experience, and with the increasing application of radiography this book will be appreciated to an increasing extent. It is an admirable production both from the point of view of the authors and the publishers.

By ANCEL ST. JOHN, Ph.D., and HERBERT R. ISENBURGER, pp. 232, with about 100 illustrations. Published by Chapman & Hall, Ltd., 11, Henrietta Street, Covent Garden, London, W.C. Price 21s. 6d. net.

The Electrochemical Behaviour of the Tin-iron Couple in Dilute Acid Media

With the object of overcoming the corrosion of tin-plate the importance of investigating the electrochemical relations of tin and iron in different liquid media has long been recognised, but interpretation of the work done in the past has been rendered difficult by the peculiar reversal of potential which occurs under certain conditions. Thus, tin is sometimes anodic and sometimes cathodic to iron. The mechanism of these changes is more clearly understood as a result of the investigation briefly referred to in this article.

THE tin coating of tin-plate at present manufactured always contains minute cracks and pores where the steel base is exposed; thus, tin-plate in contact with anelectrolyte gives rise to many small cells of the type

Tin | Electrolyte | Iron.

The current due to these couples is a major factor in the corrosion of tin-plate, and a knowledge of the factors determining its magnitude and direction is the reforeof practical importance.

Since the standard electrode potential of tin against stannous ions is $-0{\cdot}136$ volt on the hydrogen scale, while that of iron against ferrous ions[1] is $-0{\cdot}441$ volt (gold being reckoned as positive towards hydrogen), it was assumed that tin is cathodic towards iron in the tin-iron couple as it occurs in corroding tin-plate. Thus Mantell and Lincoln[2] explained the perforations which sometimes occur in the "tin can" as due to anodic dissolution of the steel base, where it is exposed at the imperfections in the tin coating. But, in practice, tin-plate has been found to give very much more satisfactory results than could possibly be the case if the exposed steel base invariably suffered anodic attack. In fact, Mantell and King[3] showed that a tin-iron couple immersed in several strong electrolytes initially gave an e.m.f., as measured on a high-resistance voltmeter, indicating that the iron was the anode, but this e.m.f. *reversed* after a few minutes and the iron became the *cathode*. This important result has been confirmed by Kohman and Sandborn,[4] Lueck and Blair,[5] and Morris and Bryan,[6] and has been found to be true for the tin-iron couple immersed in corroding media of practical importance, such as fruit juices and pure solutions of the organic acids they contain. In such cases, once the tin and iron electrodes have reached the steady condition where the iron is cathode, the tin coating of tin-plate affords electrochemical as well as mechanical protection, just as does the zinc coating of galvanised iron. Nevertheless, it must be remembered that under other conditions, notably when tin-plate is in contact with hot water, the iron becomes and remains the anode.[7]

Considerable controversy has ensued concerning the cause of this variable behaviour of the tin-iron couple. It has been pointed out[8] that the standard electrode potentials of tin and iron give no certain information as to which metal is anodic in corroding tin-plate owing to the unknown concentrations of tin and iron ions near the electrodes. Mantell and King[9] suggest that an oxide-film builds up on the iron causing it to become cathodic towards tin; Kohman and Sandborn,[10] however, observe that the reversal of the e.m.f. could as well be explained by the dissolution of an oxide-film on the tin.

A clearer knowledge of the mechanism of the tin-iron couple, and particularly of the factors which determine the direction and magnitude of the current flowing, is essential before methods for minimising tin-plate corrosion can be devised. In a paper on the subject by T. P. Hoar, M.A., Ph.D., the principles determining the direction of the current are elucidated; measurements of the change of electrode potential with time of tin and iron electrodes, alone and in couple, in various acid media, are used to demonstrate the nature of the reversal of the e.m.f., which is shown to be due to the dissolution of the initial oxide-films on both metals. Futhermore, the magnitude of the current flowing in the tin-iron couple is correlated with the amount of corrosion suffered by each electrode.

As a result of his investigation, which is described and discussed in the paper, the author shows that the corrosion of tin and iron in the tin-iron couple is quantitatively connected with the current flowing in the couple. Local action on both metals also plays an important part in the corrosion. In general, it may be said that both the couple current and the local currents will be reduced by any agency which increases the cathodic and/or anodic polarisation of both metals. In particular, the cathodic polarisation of iron is of paramount importance, because under the nearly air-free conditions obtaining in practice, the only cathodic reaction of any magnitude is hydrogen evolution at the iron cathode, and the total anodic dissolution of both metals must always be exactly equivalent to the total cathodic reaction. Therefore, further work on the minimising of tin-plate corrosion should be mainly directed towards the discovery of inhibitors of the cathodic reaction at the iron surface. These may either take the form of (*a*) additions or alterations to the steel base, or (*b*) additions to the corroding medium.

The paper containing the results of this investigation is one of a series carried out on behalf of the International Tin Research and Development Council, a complete list of those published being as follows:—

Series A.

No. 1. The Electrodeposition of Tin from Sodium Stannate Solutions with the Use of Insoluble Anodes.

No. 2. Tin-iron Alloy in Tin-plate with Notes on Some Imperfections.

No. 3. A Microscopic Examination of Iron-tin Reaction Products.

No. 4. The Corrosion of Tin and its Alloys. Part I. The Tin-rich Tin-antimony-copper Alloys.

No. 5. The Electrochemical Behaviour of the Tin-iron Couple in Dilute Acid Media.

Series C.

No. 1. The Féry-Carbone Dry Tin Accumulator.

Copies of these publications may be had on application to the Offices of the International Tin Research and Development Council, Mansfield House, 378, Strand, London, W.C. 2.

1 Lewis and Randall, *Thermodynamics* (McGraw-Hill, 1923), p. 443.
2 *Can. Chem. Met.*, 29, Feb., 1927; *Iron Age*, 119, 843, 1927.
3 *Trans. Amer. Electrochem. Soc.*, 52, 435, 1927.
4 *Ind. Eng. Chem.*, 20, 76, 1928; *Canning Age*, 9, 127, 381, 1928.
5 *Trans. Amer. Electrochem. Soc.*, 54, 257, 1928.
6 D.S.I.R. Food Investigation Board, Special Report No. 40, p. 53.
7 Macnaughton, Clarke and Prytherch, *J. Iron and Steel Inst.*, 125, 159, 1932.
8 Kohman and Sandborn, *Canning Age*, 9, 381, 1928.
9 *Trans. Amer. Electrochem. Soc.*, 52, 435, 1927.
10 *Ibid.*, 443, 1927.

The contract between the Polish Government and the Westinghouse Brake and Saxby Signal Co., Ltd., signed on April 24 last, for the manufacture and fitting of brakes on the Polish railways has been ratified. The value of this contract is £4,800,000, and the work is to be performed over a period of six years.

BLAST-FURNACE PRACTICE.

The First Report of the Blast-furnace Practice Sub-Committee (Special Report No. 6), which is a Sub-Committee of the Blast-furnace Committee of the Iron and Steel Industrial Research Council, was presented at the recent annual meeting of the Iron and Steel Institute. The Report covers a wide field, and deals with foundry iron, basic iron, and hematite iron; raw materials; furnace lines; gas offtakes; tuyeres, and blast-furnace penetration, etc.; and it also contains an appendix on the Resistance of the Blast-furnace Burden of the Flow of Gases by Dr. M. A. Vernon.*

IN presenting this Report the Sub-Committee emphasises that most of the data submitted and the deductions drawn refer to practice as it existed at the beginning of 1933. The results reported are those of a period of poor trade conditions, and in the case of many plants cannot be regarded as representative of best possible practice, as these were working below capacity. The Sub-Committee, however, considered it desirable to proceed, even though the data submitted did not represent best practice, as an indefinite delay might have resulted if the Report had been held up until normal conditions had returned. A steady improvement in productive efficiency, however, has taken place since the data were collected. The departure of this country from the gold standard, and the adoption of a protective policy, have allowed a number of firms to proceed with the development of schemes for the improvement of productive efficiency, and even while this Report has been in course of preparation particulars have been received from individual works indicating marked reductions in fuel consumption and increased output.

A feature of importance which is brought out by a general survey of the data submitted is the low output per furnace in Great Britain as compared with that in the Dominions. In fact, the average production capacity per furnace is lower in this country than in any of the other principal world producing countries. This is due to at least four factors :—

1. Great Britain was a pioneer iron producer; consequently a number of the older small furnaces still remain in operation.
2. Blast furnaces in Great Britain serve a widely varying market, and flexibility has therefore been a factor of first importance.
3. The furnaces having the lowest productive capacities in this country are generally those using low-grade iron-bearing materials.
4. For either financial or other reasons British manufacturers have not given such attention to the necessity for grading materials as have American and Continental producers.

Nevertheless the output per furnace has steadily risen during recent years, due partly to the shutting-down of some of the older plants, and partly to the gradual increase of productive capacity of those in operation. Financial limitations, however, have retarded the rate of progress in this direction, as any substantial increase of output at some of the older works of the country would necessitate expenditure not only on the blast furnace itself, but on the whole of the auxiliary equipment—blowing engines, stoves, and mains,—and the provision of the necessary funds for such expenditure has been impossible under the depressed conditions in the industry during the past few years.

At the same time the necessity for flexibility has limited the size of even the largest furnaces in this country. The competitive power of the industry has increased as a result of the country's departure from the gold standard and of the introduction of tariffs, but it is doubtful whether conditions will be such as to justify in the future the large outputs of the United States and the Dominions. The difficulties of maintaining the output of such large producing units during the past three years are in themselves a justification of the British policy of smaller furnaces and greater flexibility. It may be expected that the present policy will be continued in the future, and that the individual furnace capacity will be increased only as far as is compatible with flexibility and low-operating cost.

The third and fourth factors need examination from an entirely different standpoint. With unsized and ungraded ore of low iron content, a prolonged time of contact in the furnace was absolutely essential, and this is a factor of first importance in limiting furnace output. With improved ores, graded and, if possible, concentrated, a considerable increase in furnace output can be anticipated.

The above factors are for the most part outside the control of the blast-furnace manager, as they involve economic, financial, or technical considerations which do not come within the province of his customary duties. Bearing these factors in mind, the results reported—particularly the low fuel consumptions shown by a number of furnaces—indicate a high degree of technical ability on the part of British blast-furnace managers. Progress in future will largely depend upon :—

1. The necessary capital becoming available for the modernisation of the older plants of this country, and
2. The technical solution of the problems of the treatment of materials—particularly ores and coke—involved in the furnace reactions.

Pending such a solution, it is not possible for the Sub-Committee to make any attempt to specify the optimum furnace size that will be most economical in the future; this will be a matter for determination in each individual case.

*Published at the Offices of the Iron and Steel Institute, 28, Victoria Street, London, S.W.1.

World Tin Consumption.

The June bulletin of the Hague Office of the International Tin Research and Development Council shows that the world consumption of tin for the year ending April 30, 1934, was 129,700 tons, or 30% higher than for the preceding year, when consumption was 99,621 tons. It is noteworthy that the increased demand is widely distributed. This is shown in the following table, which gives the demand from the principal countries and the world total :—

	Twelve Months ending April.	
	1933.	1934.
United States of America	37,090	58,352
United Kingdom	17,478	20,563
Germany	8,911	10,686
France	9,393	9,925
Italy	3,711	4,069
U.S.S.R.	2,715	4,915
British India	2,137	2,000
Total	81,435	110,510
Total World	99,621	129,700

The recovery in the United States is indicated by the Babbitt metal production figures, which show an increase of 70% for the twelve months under review when compared with the previous twelve months. The tinplate and automobile industries, both important creators of demand for tin, steel, and other basic materials, show substantial increases.

Year ending April 30.	Automobile (Units).	Tinplate (Tons).
1933	2,057,000	2,270,000
1934	3,380,000	3,350,000

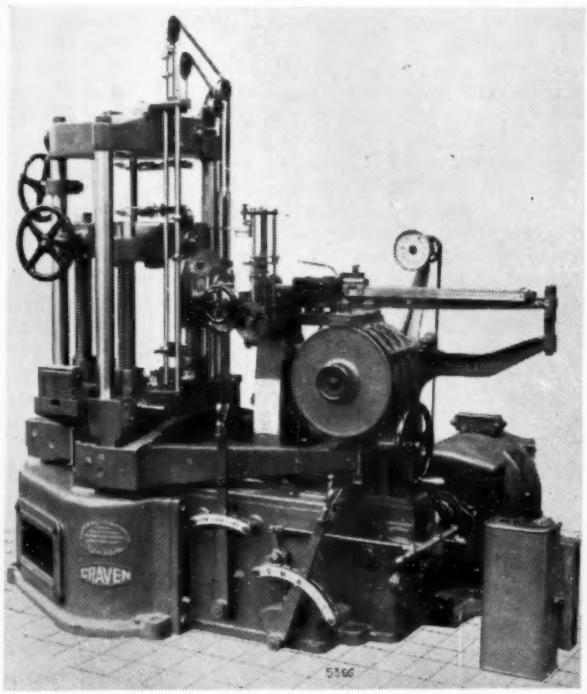
The output of automobiles during April, 1934, was approximately 460,000 units, compared with 254,800 during April, 1933, and 204,600 during April, 1932.

Sodium silicate cement, which is resistant to all strengths and temperatures of hot and cold acids except hydrofluoric, has been introduced for pickling tanks and pickling department floors. The material is quick-setting and self-hardening, taking an initial set at 70° F. in 20 to 25 minutes after mixing the powder with a solution of sodium silicate. After three days at this temperature, the cement is ready for use without further treatment. Compressive strength of the material is approximately 2,400 pounds, and the tensile strength 350 pounds per square inch. It adheres to brick, stoneware, iron, steel, lead, wood and glass.

Recent Developments in Tools and Equipment

50-ton Buckton Universal Compound Lever Testing Machine.

CONSIDERABLE interest is attached to the 50-ton multi-lever testing machine recently installed in the new Central Research Department of the United Steel Companies Ltd. The machine is capable of carrying out tests in tension, deflection or compression, and is fitted with an automatic recording apparatus. It is designed to accommodate specimens up to 28 in. stretched length between grip boxes in tension, up to a maximum of 28 in. between platens in compression, and up to a maximum span of 36 in. in deflection.



50-ton "Craven-Buckton" testing machine capable of carrying out tests in tension, deflection, and compression.

The load is imposed by a 5 h.p. variable speed motor having a range of from 300 to 1,200 r.p.m. acting through a change speed gear box and rotating three long gunmetal nuts which are in engagement with the three pulling screws connected to the straining crosshead. The gear box is so designed that the operations of starting, stopping and quick returning are all under the control of one lever, so that the driving motor can be left running continuously. The only case in which the motor is reversed is when it is desired to adjust the crosshead downwards on the fast gear or when it is desired to return slowly. There are 57 speeds available, ranging from $\frac{1}{32}$ in. per minute to 2 in. per minute, with adjusting speeds from 2 to 8 in. per minute.

Measurement of the load is by means of a travelling poiseweight and steelyard connected by a compound lever system with a floating table which supports the upper grip box by three vertical struts, and which receives the load reaction from one end of the test-piece. The levers are fitted with special hardened knife edges and seats and recoil apparatus is provided to prevent dislocation of the parts when a test-piece breaks. Two ranges of load are given by a split poiseweight, 0 to 50 tons and 0 to 5 tons, the poiseweight being traversed along the steelyard by a handwheel actuating a screw and nut, through spur gear meshing together in the same plane as the steelyard fulcrum, so that the weight is moved without disturbance to the equilibrium of the steelyard. A quick adjustment of the poiseweight is provided. When using the combined poiseweight, the steelyard scale reads up to 50 tons by 1 ton increments, and the micrometer dial reads up to 1 ton by hundredths. When using the small poiseweight the steelyard scale reads up to 5 tons by increments of $\frac{1}{10}$ of a ton, and the micrometer dial up to $\frac{1}{10}$ of a ton by thousandths. Tension testing is carried out between the upper and lower straining heads, which have open sides for the ready insertion of the test-piece; the grips are operated by hand wheels.

The autographic recording apparatus is suitable for tensile, compression and deflection tests. It comprises a revolving barrel and moving pencil actuated by the movement of the poiseweight and the yield of the specimen, so as to produce a stress-strain diagram of the test. This recording apparatus includes an extensometer system for transmitting the extension of ordinary tensile test pieces from clips on the actual test-piece and not from the grip boxes of the machine.

The construction of the whole machine is such as to secure the rigidity necessary for accurate results in addition to the strength required for the transmission of the load. The grip boxes are of cast steel, and the base, gear box, etc., are of cast iron. All the driving gears are accurately machine cut, thus minimising noise; they are totally enclosed, which keeps the gears free from dirt, and the gear-box is constructed so that the gears may be run in oil.

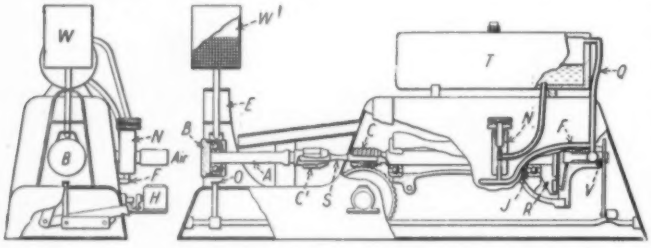
This machine, which has been supplied by Craven Brothers (Manchester) Ltd., is particularly suitable for carrying out tensile tests at elevated or depressed temperatures, since it has a definite range of speeds within which almost any desired speed of straining may be obtained, and is able to produce an autographic record. Special grips are used for these particular tests to obviate any possibility of slip between test-piece and grips which would alter the rate of straining. This is done by having a thick steel plate on each straining head through which passes a screwed connecting rod, the position of which is fixed by a screw forming a ball-and-socket contact with the plate. For high temperature work, a chromium-plated furnace, suspended from the upper straining head, surrounds the test-piece, and is wound with resistance wire in such a way as to give uniformity of temperature over the length of the test-piece. An attachment for testing at temperatures below normal can similarly be accommodated.

A New High-Speed Fatigue Testing Machine.

A shorter and less expensive method of determining the endurance limits of materials by the use of a high-speed fatigue testing machine, driven by an air turbine, operating over a range of speeds from 5,000 to 30,000 r.p.m., is described by G. N. Krouse, in a paper presented at the recent annual meeting of the A.S.T.M. Various accelerated tests to determine an endurance limit for a ferrous metal have been proposed, but it is claimed that none as yet devised have proved thoroughly reliable. The author states that increasing the speed of cycle applications seems to be a more promising method of shortening the time required to determine the endurance limit, provided the speed effect may be estimated with a fair degree of accuracy. The rotating-cantilever-beam type of fatigue machine seems well fitted for high-speed operation, and a directly connected air turbine a most satisfactory driving motor.

A machine has been developed which operates under air pressures, ranging from 10 to 40 lb. per sq. in. This machine, which is shown in Fig. 1, has been in successful use for over a year in the materials testing laboratory of the University of Illinois. As will be noted in the illustration, the specimen, S, is gripped at one end by a driving chuck C, which is tightened through an opening in the machine casing above the chuck by means of a pair of end winches. The other end of the specimen is held in a similar chuck C', on one end of the loading arm A, the other end of which rotates in the loading bearing B. The shot container W is supported on the bearing B by a slender rod guided through holes in the support E. The ball-bearing turbine shaft is driven by a disc rotor R, which in turn is driven by a high velocity blast of air impinging on the rotor blades. Air under pressure is fed to nozzles through a quarter-turn valve V. When a specimen fails, the bearing B and the shot container W drop on the cut-off button O, causing the spring-actuated air valve V to close, stopping the turbine. A revolution counter H driven by a 100 to 1 worm gear reduction, records the number of cycles of stress.

Continuous, constant-speed operation of the machine, and satisfactory wear of the bearings depends largely upon proper lubrication which is provided by a continuous spray of oil. In Fig. 1, the airtight oil tank T is maintained under air-line pressure through tube Q. Tube F leads from tube Q to the low-pressure side of the turbine where it ends in a small jet J, directed into the ball race near the



High-speed fatigue testing machine.

rotor R. A regulated amount of oil, flowing from the tank T through the needle valve N into the tube F, is caught in the air stream and issues from the jet J in the form of a fine spray. Since the differential pressure across the needle valve N is due principally to the static head of oil above the valve, changes in air-line pressure do not affect the oil flow. The oil spray, after emerging from the bearing near the rotor R, is caught up by the exhaust air and carried along the turbine shaft through the ball race and exhaust ports to the atmosphere. The exhaust air and oil spray are deflected downward by the surrounding machine casing and the oil is caught in the bottom of a galvanized iron box, which encloses the entire machine, while in operation. The collected oil, after filtering through several layers of cloth, may be used again. Less than a half gallon of oil has been used on the machine to date. One tank full of oil, about a third of a pint, it is stated, will keep the machine lubricated for four days when running at 10,000 r.p.m. and one day when operating at full speed.

It has been found, as will be shown, that within the speed range of this machine, 5,000 to 30,000 r.p.m., even a considerable variation of speed has little effect upon the test results, hence the machine speed may be controlled satisfactorily by means of a gate valve on the air supply line. A pressure gauge between the gate valve and the machine shows the pressure available, 10 lb. per sq. in. being sufficient to operate the machine at 10,000 r.p.m. while 40 lb. per sq. in. will operate the turbine at 30,000 r.p.m.

The loading weight on the specimen consists of the combined weights of the bearing B, shot container W, lead shot and a proportionate part of the loading arm A. The lever arm of the loading weight is the distance between the axis of the rod supporting the shot container and the critical section of the specimen. This distance is measured by means of a trammel divider, one leg of the divider being placed in the holes of the weight support E and the other leg adjusted to reach the critical section of the specimen. The distance between the divider points is measured along a scale. The maximum stress in the specimen is computed by the ordinary flexure formula.

The Speedomax Radiation Pyrometer.

A new radiation recording pyrometer has recently been developed by Leeds and Northrup Co., which is noteworthy; it is claimed to effect temperature measurements of a nature previously considered to be impossible. The instrument has been termed the "Speedomax." An outstanding feature of this instrument is its ability to record the temperature of steel automatically as the steel moves along the roll mill, between stands or after the final pass. It is so quick in its registration of temperature that, in two seconds the recorder pen shoots across the entire 10-in. width of chart and comes to balance. It is claimed to be ten times as fast as the usual industrial recorder, and to be capable of measuring any quantity that is convertible into millivolts.

This radiation pyrometer consists of two elements—the Speedomax recorder and a radiation thermotube. Each is a recent development of the research and engineering staffs of Leeds and Northrup Co., and each is now thoroughly tested in the field in actual plant operation. The recorder operates on the well-known potentiometer principle, but the usual galvanometer and mechanical balancing mechanisms are replaced by an electrical system which makes the instrument ten times as rapid. In securing this responsiveness, accuracy has not been sacrificed, and the instrument is extremely rugged, so that its balancing is unaffected by ordinary vibrations. It is built to operate continuously under steel mill conditions. It requires 115 volt, 60 cycle power supply. With other power supply a rotary converter, motor generator set, or transformer is used. The radiation thermotube has characteristics which adapt it for use with the recorder to constitute a radiation pyrometer admirably suited to record temperatures accurately and to follow changes rapidly. The tube responds very quickly to variations in energy radiated. Two seconds after a hot billet comes into line of sight, its temperature has been recorded. Any change in temperature along the billet itself is recorded in a fraction of a second.

With this instrument it is claimed that the retarding of rolling operations is no longer necessary, nor is it necessary in any way to delay production to obtain reliable measurements and continuous records. It is amply fast to record the temperature drop due to water spraying on the hot steel, during a temporary pause, when roll table speed is not synchronised with roll speed. It will show when one part of a slab is hotter than another, due to improper operation of the reheating furnace, and can be used as a guide in operating the furnace to get any desired temperature condition in the product. Analytical studies can be made for conditions indicated by temperature variations, since the rapidity of chart movement in the recorder can be increased from its normal speed of 4 in. per hour to a speed of 2 in. per min., which gives a clear graph of even extremely rapid temperature fluctuations. The slower chart speed is provided for standardised mill operations, and the chart may be run continuously or only when significant temperatures are being recorded. Standard ranges are 1,000 to 2,200° F. and 1,300 to 3,000° F. Special ranges up to 5,000° F. can be furnished.

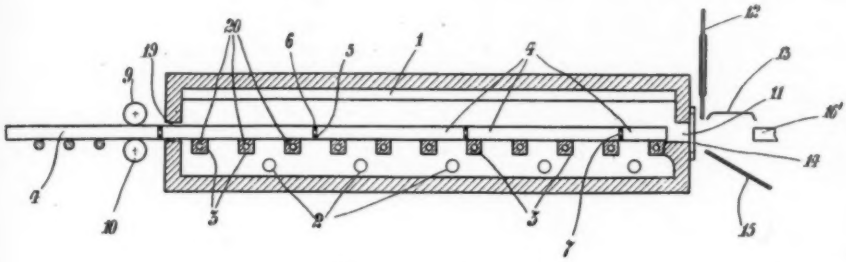
There are many applications for this type of pyrometer. Mention may be made of its use in pipe mills for recording temperatures as skelp leaves the bell; in strip mills for temperatures on final pass of roughing mill and after the last pass on the finishing mill; in plate mills, for temperatures before and after the finishing pass; in wire mills, for temperatures of billets as tongs take them from the furnace to rolls of the first pass; and similarly it may be applied to rail mills, slab mills, sheet mills, rod mills, etc. Further particulars regarding this development are available from the Integra Co., Ltd., 183, Broad Street, Birmingham.

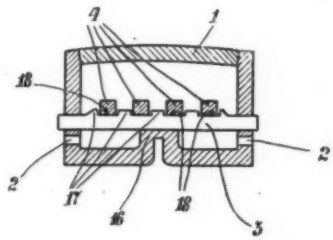
Some Recent Inventions.

The date given at the end of an abridgment is the date of the acceptance of the complete Specification. Copies of Specifications may be obtained at the Patent Office, Sale Branch, 25, Southampton Buildings, London, W.C. 2, at 1/- each.

Billet Heating Furnaces.

IN a furnace recently developed for the production of hot billets, in which metal pieces are welded together, arrangements are made for the bars to advance continuously, instead of by step-by-step movement. For this purpose transverse bearers are provided throughout the length of the furnace, above a number of fuel ports or burners, arranged so that the metal bars have the hot gases from the burners circulated around them.





Longitudinal and vertical sections of a recently developed billet heating furnace.

This furnace, shown in the accompanying illustrations, is of the continuous type, and has a combustion and heating chamber 1 fired by burners entering ports 2 along the two longitudinal sides of the furnace. The firing of the furnace illustrated is effected by oil fuel and air, but, alternatively, the furnace may be fired by coal, producer gas, coke-oven, or blast-furnace gas, powdered fuel or other known means, and the air for combustion may, if desired, be pre-heated.

The combustion and heating chamber 1 is bridged by a series of cross bearers or supports 3, these taking the place of the customary hearth, with or without skids, of existing so-called continuous furnaces. On these cross bearers 3, the metal bars 4 to be heated are adapted to travel longitudinally through the furnace. The cross bearers 3 are arranged above the burner ports 2, and the hot gases circulate all round the bars 4.

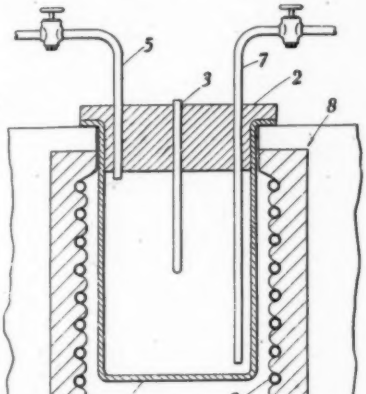
To ensure continuity of operation, each bar 4 is attached to the bar or bars in advance and/or at its rear by flash welds 5, 6. The welding of each bar to its predecessor is effected before the whole of the said preceding bar enters the furnace.

To prevent the formation of cold spots, the feed rollers 9, 10 are operated to reciprocate the lengths 4 longitudinally within the furnace ; when it is desired to cut off a length necessary for a billet, the rollers 9, 10 are operated so as first to eject, through the discharge opening 11, the necessary length which is cut off by a hot saw 12, and then to draw the remainder of the bars 4 back into the furnace. The length of the cut billet is determined by the position of an adjustable stop 16^1, while a hood 13, filled with a suitable gas, is provided to prevent excessive scaling of the ejected length. The supports 3 are formed with channels 20 for air or water cooling, and, as shown in Fig. 2, are supported at the middle by brickwork piers 16, which also may be air or water cooled. The members 3 may either be formed with projections 17, which provide spaced parallel tracks for the bars 4, or have welded to their upper surfaces facings of heat-resisting steel having curved upper surfaces on which the bars 4 slide.

402,979. Stewarts & Lloyds, Ltd., Oswald Street, Glasgow, and G. S. McLay, Chipperfield, Hertfordshire. December 14, 1933.

Bright Annealing Alloys.

IT is well known that in some processes for annealing it is customary to introduce a current of gas into the annealing furnace, which may either be a neutral or a reducing gas. With some alloys annealed by these processes, however, such as brasses, there may result differences in the compositions of the alloys, due to the gas stream carrying away a volatile constituent. In a recent development such alloys are annealed in an atmosphere which is non-oxidising, and which consists of a reducing constituent, within a gas-tight, externally heated chamber, within which the same charge of gas is maintained during the time the alloy is at a temperature at which an appreciable loss of its volatile constituent would otherwise occur. By this process the surface of the alloy is kept bright, and no appreciable change in the constitution of the alloy is effected.



Bright annealing furnace.

The essential parts of the annealing furnace for this process are shown in Fig. 1. In operation the cast-iron pot 1 is filled with the alloy to be annealed, the lid 2 is then sealed in place. The steel tube 7, which passes through the lid, is then connected to a train of purifying vessels, whereby hydrogen of ordinary commercial purity is deprived of most of its oxygen and water vapour. The taps on 7 and 5 are opened and a stream of the purified hydrogen is passed through the pot to sweep out the air. The tap on 5 is then closed ; that on 7 remains open, so that the interior of the pot is still connected to the supply of hydrogen, to safeguard against any leak which might develop in the chamber during the annealing operation. The pot is then heated by means of the furnace to the annealing temperature and maintained at that temperature for a suitable period. The temperature and period will depend on the nature of the material to be annealed ; but a period of 2 hours at 650° C. may be regarded as typical for brass. The pot is then cooled ; when atmospheric temperature has been nearly or quite attained, the tap on 7 is closed and the pot opened. The wire, or other brass material, thus annealed is kept bright, and the constitution of the alloy of which it is composed remains practically unchanged.

404,292. The General Electric Co., Ltd., Magnet House, Kingsway, London, S.W., and M. C. Caplan, Research Laboratories, General Electric Co., Ltd., Wembley, Middlesex. January 1, 1934.

Zircon Concentrates.

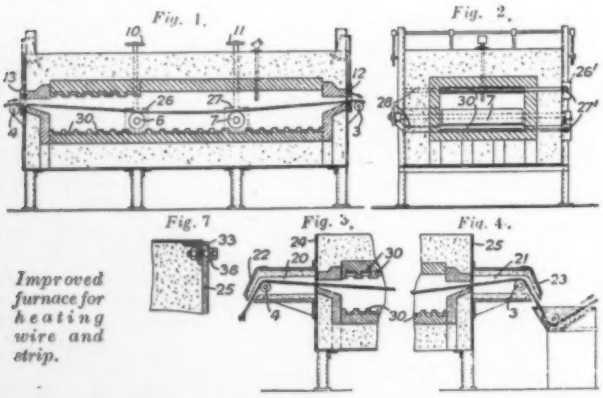
Zircon is separated from other constituents of mineral sands by treating the sand to produce selective oiling of the zircon particles and then forming a froth containing the

oiled particles. The froth may or may not float on the surface of the pulp and in the latter case is separated from the unoiled particles by passing the pulp over shaking tables or jigs. A sand containing zircon, rutile, monazite, ilmenite, garnet, quartz, cyanite, etc., is perferably first treated by magnetic separation to remove the ilmenite and most of the monazite and is then washed on shaking tables to remove the quartz. The residual sand is then agitated, preferably with a very dilute soap solution and an oil such as pine oil, eucalyptus oil, cresol, or a higher alcohol, to form a froth. A thicker oil or fat such as oleic or other unsaturated fatty acid, olein or a similar glyceride, phenol of cresol, or sulphonated derivatives of any of these substances is preferably added to cause flocculation of the oiled zircon particles, the thicker oil or fat being preferably dissolved or dispersed in an alkali such as ammonia or caustic soda, or in an alcohol, or in the frothing oil. To prevent oiling of the rutile, monazite, etc., the pulp is preferably made alkaline and the sand may be treated with an acid and then washed with water prior to agitation in the oily soap solution. The flocculation of the zircon particles may be improved by the addition of small amounts of soluble salts of metals such as magnesium, zinc, lead, copper, or the alkaline earth metals, which produce insoluble soaps. The froth may be formed in a rotating cylinder provided with agitating baffles or riffles, from which the pulp is passed over a small shaking table, the froth of oiled zircon particles being washed off by a slow current of water, or alternatively the froth may be formed in a sub-aeration flotation machine. The zircon concentrate obtained in either case may be cleaned by washing with acid and then with water and retreating to produce a froth of the zircon particles. The soap used in the frothing process may be for example sodium oleate, sodium palmitate, sodium stearate, or the corresponding potassium salts, or the alkali salts of sulphonated derivatives of unsaturated alcohols, such as sodium oleylsulphonate. In some cases the soap may be omitted and the zircon froth produced by a mixture of a frothing agent and olein, oleic acid, or other fatty or tarry oil. Specification 406,043 is referred to.

406018. M. A. Corbett, 90, Church Street, Chelsea, London.

Wire and Strip Furnaces.

An improved furnace for heating wires or metal strips has been developed in which the wires or strips are moved by means of transporting rollers through the tunnel-shaped furnace chamber heated by electric heating



Improved furnace for heating wire and strip.

elements. It is a continuous furnace of a kind in which the wire or strip hangs in a curve between the conveying-rollers 3, 4, the lower part of the curve is supported by rollers 6, 7 covered with refractory material and disposed near the middle of the furnace at a level considerably lower than that of the rollers 3, 4. The latter and the closure plates 12, 13 at the ends of the furnace are adjustable vertically, either together or independently. The rollers 6, 7, which are driven at the same peripheral speed as the rollers 3, 4, are removable through side openings normally covered by plates 26, 27, and are vertically adjustable by hand-wheels 10, 11 so that the position of the strip with relation to the heating means can be controlled. The furnace is heated by transverse electric resistance elements 30, which are removable either singly or in groups. As shown in Fig. 2, each element 30 can be removed laterally, after detachment of the casing 26' and the connection 27', through an aperture in the furnace wall closed by a removable plug 28. Figs. 3 and 4 show a modification in which the rollers 3, 4 are mounted in end chambers 20, 21 having downwardly-extending lips 22, 23 and adjustable vertically on the end plates 24, 25. To permit free expansion and contraction of the latter, the holes through which extend the securing bolts 33, Fig. 7, are enlarged or elongated and spring washers 36 are fitted.

401584, E. F. Russ, 37, Kaiser-Friedrich Ufer, Cologne, Germany. November 16, 1933.

Treating Metallic Surfaces.

Aluminium or aluminium alloy anodes for electrolytic condensers and rectifiers are treated so as to form a comparatively thick low-resistance oxide coating either chemically or by the electrolytic action of direct current, the anode then having a dielectric thin oxide coating deposited thereon electrolytically by direct current. The low-resistance film may be formed chemically by immersion in a solution containing 3% of sodium carbonate and 3% of sodium bicarbonate at a temperature of about 98° C. The electrode is then dipped in dilute nitric acid and washed in distilled water. Other metallic salts may be added to the solution of carbonates. Solutions containing the hydroxides of the alkali or alkaline earth metals may also be used, preferably at a lower temperature such as 45° C. The coated electrode is then introduced into an electrolyte of the borate, phosphate, or tungstate type, where the dielectric oxide coating is deposited electrolytically.

397,538. British Aluminium Co., Ltd., A. G. C. Gwyer and A. N. D. Pullen, Adelaide House, King William Street, London.

Increased Use of Steel Props in Mines.

ENCOURAGING news of the increasing use of steel supports for roofs and sides is mentioned in the report of Mr. E. H. Frazer, Divisional Inspector of Mines for Yorkshire, published by H.M. Stationery Office.

In eight collieries steel props were used for the first time in 1933. The total number of steel props used in the faces of 43 mines was 103,750; a comparatively insignificant figure with the number of wooden props erected. There is great room for the use of more steel for face supports in suitable places, though it is not claimed that steel props could be used with economy in thin seams, or in places where the pressure is not sufficient to break the wooden props now employed.

There is a continued addition to the number of steel props, and it has been calculated that owing to the decrease in output during the year, and the use of more steel supports, there must have been at least 600,000 fewer wooden props purchased for use in the faces of Yorkshire mines in 1933 compared with the year before.

Workmen's officials at Maltby Colliery voluntarily reported that steel props had improved the conditions considerably both in the face and roads. In regard to steel arches, 205 miles of working roadways were supported by them at the end of 1933, compared with 167 miles at the end of the previous year. Four collieries could boast of 12 miles or more of steel-arched roads, including Askern Main Colliery, where the arches have all been installed within three years. Thirty-four miles of roadway in 62 mines were supported by cambered girders, compared with 28 miles twelve months before. The workmen's inspectors at Markham Main Colliery evidently recognised the value of cambered girders because they asked in their official report for more to be set.

Business Notes and News

Memorial to Wollaston.

An interesting ceremony was performed on Wednesday, July 4, when a memorial plaque to William Hyde Wollaston, the chemist and natural philosopher, was unveiled at 14, Buckingham Street, W. 1, where Wollaston lived for 25 years.

Born at East Dereham, Norfolk, in 1766, Wollaston was educated at Charterhouse and Caius College, Cambridge, and was elected a Fellow of the Royal Society in 1793. His original work, which is of a very diverse nature, deals mainly with chemical subjects, and he made a special study of the platinum metals. Wollaston discovered how to work platinum on a practical scale, and was the first to detect palladium and rhodium. The latter, it may be noted, have been recently applied in the form of electro-deposited coatings to give an untarnishable finish to other metals; palladium, moreover, is becoming increasingly popular for jewellery, and has important uses in dental alloys, for artificial-silk spinerettes, for electrical contacts, and as a catalyst in chemical processes.

On his death, in 1828, Wollaston left a sum of money for "the promotion of researches concerning the mineral structure of the earth," in connection with which a medal, bearing his name, is awarded annually by the Council of the Geological Society of London.

An appreciation of Wollaston's scientific work was given in an address by Sir Frederick Gowland Hopkins, President of the Royal Society, who afterwards unveiled the plaque. In addition to members of the Wollaston family, there were present representatives of the Scientific Societies, including Mr. J. F. N. Green, President of the Geological Society of London; Dr. G. T. Morgan, President of the Chemical Society; Sir Thomas Holland, President of the Mineralogical Society; and Sir F. J. M. Stratton, President of the Royal Astronomical Society.

Stream-lined Rail Cars.

The first express service of stream-lined, heavy-oil cars in this country is shortly to be opened by the Great Western Railway Company between Birmingham, Gloucester, Newport, and Cardiff. A stream-lined car has been running since the beginning of February between Sough, Reading, and Oxford, and has covered in these four or five months over 20,000 miles and carried 50,000 passengers. It is, in fact, the success of this experiment that has led the Company to build these new cars of similar design with more powerful engines for a morning and afternoon express service in each direction between Birmingham and South Wales.

The cars will be driven by twin engines, each of 130 h.p., using non-inflammable heavy oil. Capable of a maximum speed of about 80 miles an hour, they will cover the journey of 117 miles between Birmingham and Cardiff at an average speed of just under 50 miles an hour. The fastest service at the present time takes 2 hours 50 minutes; the fastest new car will take only 2 hours 22 minutes.

The whole of the mechanism of these stream-lined cars is carried beneath them, so that practically the whole of the floor space is available for the use of their 40 passengers. The cars have been designed and are being furnished with special regard for the comfort and convenience of those who are to travel by them.

Weardale Spar Mines.

Several Weardale lead miners have formed themselves into a company and propose to reopen certain spar mines in the district with a view to providing employment. For years the spar from which the pure lead was washed was rejected as waste, but it has now a marketable value as roadmaking material. Preparations are being made to reopen the old Redburn Spar mine, and men are already employed rigging up the necessary shafthead gear.

While producing spar, one of the promoters of the enterprise stated, we will also produce a certain amount of lead. This we shall be unable to sell because the entire rights are held by the Weardale Lead Co., which formerly worked the mines. Consequently any lead or iron will have to be turned over by us to the Company. The profits from selling spar are not large, but if matters develop as we expect we hope to reopen several mines and provide as much work as possible.

New Safety Stop for Pit Tubs.

A practical demonstration of a new runaway tub stop, upon which Hadfields, Ltd., have been conducting experiments, was given at the firm's East Hecla Works, Sheffield, recently, before members of the Yorkshire branch of the National Association of Colliery Managers. Hadfields have realised the need for a runaway tup stop that will prove effective and reliable under all conditions of service. The results of their efforts have proved so satisfactory that they are convinced they have perfected an appliance possessing all the essential features required. At normal speeds tubs can freely pass over the appliance in either direction, but should they break loose from the rope coupling and travel above a pre-determined speed on an incline on which the new runaway tub stop is installed, mechanism is brought into play which brings them to a standstill some yards farther down the track.

New Destroyers Launched.

From the Barrow Shipyard of Vickers-Armstrongs, Ltd., launches were made recently of two destroyers for the British Admiralty. They will be driven by steam turbines, and the machinery is now being built by Parsons Marine Turbine Co., Wallsend. A third destroyer, *Forester*, was launched at Cowes, Isle of Wight, on the same day.

Many people assembled to see the launches at Barrow. These included Brazilian and Portuguese officers, who are at Barrow in connection with naval work in hand for their countries. The vessels were named *Fame* and *Firedrake*, respectively.

In reply to the toast of "the builders" at the subsequent luncheon, Sir Charles Craven, managing director of Vickers, said that on the occasion of a launch at Barrow many had got into the way of looking for the announcement of a new order. He was sorry he was not able to announce an order, but they were really not doing so badly. In January of last year in the concerns over which he had control he had under 24,000 men. In January of this year the number was over 27,000. In Barrow they were now paying in wages £27,633, and were employing close upon ten thousand.

The vessel launched from the works of Messrs. John Samuel White & Co., was named *Forester*. She is the first of two destroyers ordered from that firm under the 1932 naval construction programme. Her sister ship, the *Fury*, will follow shortly, and these two vessels, with six other new ones and the flotilla leader, *Faulknor*, will complete the new destroyer flotilla of the *Fearless* class.

Indian Copper.

At the recent general meeting of Indian Copper Corporation, Ltd., Sir Godfrey Fell, the chairman, stressed the value of the Company's rolling mill. He said the market for refined copper in India was from 1,500 to 1,800 tons a year, so that with a production from their mill of 4,800 tons, but for the rolling mill, they should, after meeting the whole of the Indian market demand, have a surplus production of at least 3,000 tons a year, which, in future, would be much larger, and which they would be forced to export, thus sacrificing all the benefits of the revenue tariff in force in India on imported copper. The rolling mill was, therefore, their main source of revenue, and during the year it produced 5,643 long tons of first-class yellow metal sheet and 500 long tons of yellow metal circles, making a total production of 6,143 long tons, an increase of 13% on the previous year.

With the increased capacity now secured the Company is ready to meet any demands which might come forward, and to reap the benefit of the anxiously awaited improvement in world prices. As to the future of the copper industry, Sir Godfrey stated there appeared to be definite signs of an improvement in the statistical position. The operating profits made by the Company in 1933 were only rendered possible by the increased output and the reduced cost of production, which made up in part for the lower prices obtained for its products. Fortunately, in the current and future years, it would have a considerably larger output, which should enable it to maintain its position while waiting for the long-hoped-for industrial recovery. During the current year costs showed satisfactory reduction due to increased output and the improved lay-out and flexibility of the plant.

New Types of Plant.

In these days of specialisation and keen competition the introduction of new kinds of work is an expensive and often hazardous matter, said Mr. Harold G. Judd, at the recent annual meeting of Whessoe Foundry and Engineering Co. With this Company it has necessitated considerable increase of the technical and research department, and a large amount of investigation has been carried out, which has resulted in the development of new types of plants.—in particular, the Whessoe electrical precipitation plant, which is adapted for use in connection with blast furnaces, coke ovens, and gas works. Despite the competition of other systems earlier in the market orders have been secured for precipitation plants of this type from companies of the highest standing, and it is expected that these will be but the precursors of other orders to follow.

Among the other developments on which this Company has been working are coal-cleaning plants. After much investigation and experiment a demonstration plant is installed at the works on a system for which it holds the British licence, and which, it is believed, will compare favourably with similar plants on the market. These new developments in no way affect the continuance of the older types of work for which the Company has justly a high reputation—*e.g.*, oil tanks, gas plant, blast-furnace plant, chemical plant, and weigh-bridges.

Pit-head Baths.

Further progress in the amenities for miners has been provided by the pit-head baths at the Sherwood Colliery, Mansfield, which were officially opened recently by Mr. F. N. Ellis, Chairman of the Sherwood Colliery Company. The scheme is one of the finest in the country, for in addition to cubicles and shower baths for 2,000 men, there is provided electrical apparatus for boot cleaning and greasing, water-bottle filling, and a large cycle shed. But the most notable feature is a swimming bath, 75 ft. long, with a spectators' gallery. This is the fifth scheme of the kind inaugurated in the Notts district. Up to date there are 43 pit-head baths in the country.

In his opening address, Mr. Ellis said they were there to put the finishing touch to an enterprise of considerable magnitude. A more comprehensive scheme had not been carried through, he understood, under the auspices of the Miners' Welfare Committee. The total cost was £32,430, of which £12,250 had been received from the Notts District Miners' Welfare Committee, and that allocation was much appreciated.

Large Engine Turntables.

In order to enable larger and more powerful locomotives to be used and to speed up station working, the London, Midland and Scottish Railway is to install locomotive turntables of increased diameter at six important traffic centres—Stoke-on-Trent, Liverpool (Bank Hall depot), Manchester (Victoria), Derby, Gloucester, and Burton-on-Trent.

Three of these turntables—at Liverpool, Manchester, and Derby—will be of 70 ft. diameter. That at Stoke will be 60 ft., and that at Burton 55 ft. At Gloucester two new turntables are being installed—one of 60 ft. at the passenger station, and one of 55 ft. at the locomotive depot. The 70-ft. turntables are the largest on the system, and will permit of the Company's biggest engines being turned if necessary.

Pease & Partners Ltd.

The report and accounts of this Company were presented at the recent annual meeting, and in his address Mr. J. Frater Taylor dealt in considerable detail with the figures presented. The profit and loss account, he said, showed a balance to credit for the year of £134,897. Costs generally had been lower, and sales of ironstone, pig-iron, and foundry products had also contributed material gains. Generally there had been a substantial decrease in maintenance charges due largely to the successful policy of abandoning those collieries which had been outstandingly unprofitable.

In reference to the business outlook generally, Mr. Taylor found it difficult to prophesy. Conditions appear to be better, he said, prices are better, and there is no good reason why they should not continue so. He would very much like to see the iron and steel industry busier in the production of heavy steel, more especially for shipbuilding, and would feel much happier if he knew that North-East Coast shipbuilding, especially on the Tyne, had brighter prospects.

He felt somewhat strongly that the restoration of greater activity in shipbuilding generally is in our own hands to some extent. It should be possible to render the sale of old ships to foreign nations less easy, perhaps by giving an inducement to shipowners to sell for breaking up purposes at home.

Large Rolling Mill Plant Despatched to South Africa.

A large steel-sheet rolling mill plant, built at the works of Davy Bros., Ltd., Sheffield, for the Pretoria works of the South African Iron and Steel Industrial Corporation, has been despatched. This plant is designed for both hot and cold rolling, and is primarily intended for the production of black and galvanised sheet of all sizes and gauges, generally supplied by the sheet trade. Its capacity at present is 30,000 tons of finished sheet per year, but with provision for increasing this quantity at a later date to 40,000 tons. The installation comprises six "hot" mills, with rolls 30 in. diameter, and two "cold" sheet mills, with rolls 28 in. diameter. The whole of the mills will be driven by a single electric motor and reduction gear set. A hydraulic stretching machine is also provided for straightening the finished sheets, operated by a small hydraulic pump. Davy Bros. are also supplying two Lancashire boilers of 7 ft. 6 in. inside diameter, 28 ft. long, with economiser, boiler-feed pumps, feed-water heater, and all pipe connections. The total weight of the machinery furnished by the firm under this contract is 700 tons.

Iron and Steel Output still High.

British iron and steel production in June remained at a high level, though it did not quite maintain the high figure reached in May. Output of pig iron was 515,700 tons, compared with 527,900 tons in May and 345,600 in June, 1933. Output of steel ingots and castings was 757,500 tons, compared with 780,000 tons in May, and 568,800 in June, 1933. The decline compared with last month is partly explained by the fact that May had one more day than June.

Pig iron output for the first half of this year was 2,899,200 tons, an increase of over 1,000,000 tons, compared with the first half of last year, when production was 1,897,800 tons. Steel output for the first half of this year was 4,507,300 tons, compared with 3,182,800 tons in the first half of 1933.

Catalogues and Other Publications.

British Commercial Gas Association has recently published a booklet which deals with the use of Town's gas in glass industry. It is pointed out that in the manufacture of glass the number of processes in which an accurately controlled heat is of primary importance are so many that it is only natural that the cleanliness and controllability of gas commend this fuel to manufacturers. The booklet is well illustrated and copies can be obtained on application to the Association, 28, Grosvenor Gardens, London, S.W. 1.

An interesting brochure has been received from Armstrong Whitworth and Co. (Engineers) Ltd., Scotswood Works, Newcastle-on-Tyne, which gives useful information regarding this Company's well-known pneumatic chipping and caulking hammers. Advances, consequent upon competitive manufacture and ever-increasing application have been particularly apparent during recent years and users of these important tools should procure copies of this brochure.

A description of the exhibit of High Speed Steel Alloys Ltd., at the British Industries Fair, 1934, is given in a brochure recently received. The exhibit embraced the application of alloying metals tungsten, vanadium, and molybdenum, and gave a comprehensive display showing the improved physical qualities imparted to steel by the use of an alloy metal, or of various alloy metals in combination. Those who visited the Birmingham section were probably unable to give the time to a close scrutiny of this exhibit and a description such as is given in this brochure will be useful, while those unable to visit the Fair will benefit from the information supplied. Copies are available on application to High Speed Steel Alloys Ltd., Dilton Road, Widnes.

BLENDING COKE BREEZE FOR STEAM GENERATION.

THE large amount of coke breeze produced in connection with the operation of by-product ovens is not generally used to the best advantage. The material is burnt largely for steam generation, but it constitutes a difficult fuel, being of low combustibility and also small in size, easily falling between the firebars or being blown off the grate. In many coal and iron works the proper policy is to blend the coke breeze before combustion with low-grade coal, especially, for example, refuse material from coal washeries high in moisture content.

A typical example of what can be accomplished is illustrated at a large colliery in South Wales, which also operates extensive by-product coke-oven plant, and posseses a vast accumulation of coke breeze and dust, the result of many years' working. It was desired particularly to burn wet, slurry residue from the washing plant, averaging 20—30% moisture, and for this purpose the hand-fired "Lancashire" boilers were fitted with "turbine" forced-draught furnaces, equipped with fans and trunking in place of steam jets. This will, of course, burn any material, from the highest to the lowest-grade quality, including both washery slurry and coke breeze; but excellent results are being obtained by blending the coal washings 50 : 50 with the coke breeze, a mixture which burns much better under forced-draught conditions than either of the two products separately, the wet coal having the beneficial effect of "binding" the dry, friable coke breeze. Combustion also is absolutely smokeless, since the volatile content of the mixture is lower than 15%, representing approximately the "smoke line," while hand firing of the blend is easily carried out; and the same applies to the cleaning out, the ash being of a friable character, almost like sand, with little or no clinker. On standard 30 ft. 0 in. × 8 ft. 0 in. "Lancashire" boilers an evaporation up to 9,000 lb. of water per boiler per hour is being obtained.

The forced-draught furnace consists essentially of a number of longitudinal cast-iron trough firebars, about 6 in. wide, fixed side by side, in number according to the width of the grate required. Each of these contains a large number of small transverse bars or elements, having inclined blades underneath like a turbine, which deflect the correct amount of air between the small transverse bars to the fire above, giving uniform and sub-divided air distribution. Forced draught is always used, given either by means of steam jets, which do not as a rule take more than 2–2½% of the evaporation of the boiler, or by mechanically driven fans with trunking. In this case the power is extremely small, usually less than 2 h.p. for a standard 30 ft. 0 in. × 8 ft. 0 in. "Lancashire" boiler. Further, the firing can be either by hand or by sprinkler stoker gear, that is, of course, with a fixed grate and hand-cleaning out; while in addition there is provided, when required, an extended cleaning-out and secondary air admission grate at the back, which is useful for smoke prevention in the case of bituminous coal and also for assistance in cleaning out, part of the live fire being pushed back on to this extension to be used for igniting the fresh coal after the bulk of the ash and clinker has been removed.

There is no question that blending is one of the most neglected sources of economy in steam-boiler operation and combustion generally, which is all the more remarkable in view of the fact that blending coal on scientific lines has, of course, been used in by-product coke-oven practice for more than half a century past.

Palmers Hebburn Co., Ltd., and the North-Eastern Marine Engineering Co., Ltd., Wallsend, have obtained jointly an important contract for hull and machinery repairs and the conversion to superheating of the Argentine oil tanker, *Juvenal*, 14,000 tons gross. The vessel will arrive in the Tyne towards the end of July, and provide work for some hundreds of men for four weeks.

Some Recent Contracts.

Developing East African Goldfields.

The British Government is assisting in industrialising East Africa, and with a view to exploiting the area a preliminary programme has been developed, which provides for an expenditure of £120,000. In this programme contracts have been placed for machinery to develop the goldfields. Frank Pearn & Co., Ltd., of West Gorton, Manchester, for instance, have received an order for the supply of pumps and oil engines, and Ingersoll and Rand & Co., Ltd., Trafford Park, Manchester, have obtained a contract for air compressors, which will be used in the Lupa Territory, Tanganyika. These form part of a £20,000 order for British machinery, which is only the forerunner of larger contracts for equipment required in developing this scheme.

It is expected that the first productive operation of the goldfield will be 180,000 tons of ore, treated from a small part of the 92 square miles which have been conceded for the purpose by the Tanganyika Government. Reports in the hands of the Colonial Office indicate that roughly 60,000 ozs. of gold will be derived annually from this output alone.

The Bibby Line, Ltd., have placed an order with the Fairfield Shipbuilding and Engineering Co., Ltd., of Govan, for a large passenger and cargo-carrying twin-screw motorship. The vessel is to be 500 ft. long with a beam of 66 ft., a cargo capacity of 11,000 tons, and a gross tonnage of about 13,000. She is to have accommodation for more than 280 first-class passengers, is to embody the most recent improvements, and is to be specially designed for the owners' Mediterranean and Eastern trades. It is to be fitted with the latest type of Fairfield-Sulzer direct-injection two-stroke Diesel engines, developing 10,000 h.p. Like the last four vessels built by the Fairfield Co. for the same owners, the new ship is to be electrically operated throughout. The passenger accommodation and public rooms generally, will be larger.

Orders for 33,300 tons of rails, dog-spikes, and fishplates for the Canton-Hankow Railway, at a total cost of over £250,000 sterling, have been placed with the following firms:—The Barrow Hæmatite Steel Co., Ltd., the British (Guest Keen Baldwin) Iron and Steel Co., Ltd., the Cargo Fleet Iron Co., Ltd., Colvilles, Ltd., Dorman Long & Co., Ltd., the Lancashire Steel Corporation, Ltd., the Skinningrove Iron Co., Ltd., the United Steel Co., Ltd., Guest, Keen & Nettlefolds, Ltd., Walker & Wilson, Ltd., and the Anderston Foundry Co., Ltd.

The orders have been divided among the leading British manufacturers to ensure early shipment to Hankow and Canton. Other important orders for about twenty locomotives and a considerable quantity of rolling stock, etc., are under consideration and will be placed shortly.

Messrs. Cochran & Sons, of Selby, have secured another order for a steel screw trawler. The vessel is for Messrs. Pickering & Haldane, of Hull. This firm has four vessels on the stocks and seven more to construct, which will keep it fully occupied until the end of the year.

The British Steelwork Association announce that a large contract for aeroplane hangars, for which approximately 7,000 tons of British steel will be required, has been placed by the Air Ministry with Redpath, Brown & Co., Ltd. The structural steelwork will be fabricated partly at the Scottish works of the firm and partly at their Manchester works. There will be 13 hangars in all—seven to be erected in Iraq, five in Great Britain, and one in Egypt.

An order has been received by Richard Dunston, Ltd., of Thorne, Yorkshire, for the construction of a large, single-screw steam tug and eight river barges, to the order of London owners. Further orders also received by Dunstons during the last few days are for a Diesel-engined tug, 70 ft. long, for service on the Thames, and a steel light float, fitted with special bell-ringing and light-flashing devices, for service off the east coast.

MARKET PRICES

ALUMINIUM.

98/99% Purity	£100	0	0

ANTIMONY.

English	£43	0	0
Chinese	35	5	0
Crude	24	10	0

BRASS.

Solid Drawn Tubes	lb.	9d.
Brazed Tubes	„	11d.
Rods Drawn	„	8¾d.
Wire	„	7¾d.
*Extruded Brass Bars	„	4d.

COPPER.

Standard Cash	£30	0	0
Electrolytic	33	10	0
Best Selected	32	5	0
Tough	31	15	0
Sheets	60	0	0
Wire Bars	33	0	0
Ingot Bars	33	0	0
Solid Drawn Tubes	lb.		10d.
Brazed Tubes	„		10d.

FERRO ALLOYS.

†Tungsten Metal Powder	lb.	0	3	6
‡Ferro Tungsten	„	0	3	3
Ferro Chrome, 60-70% Chr. Basis 60% Chr. 2-ton lots or up.				
NOMINAL: 2–4% Carbon, scale 11/– per unit	ton	31	0	0
NOMINAL: 4–6% Carbon, scale 7/– per unit	„	23	0	0
NOMINAL: 6–8% Carbon, scale 7/– per unit	„	22	10	0
NOMINAL: 8–10% Carbon, scale 7/– per unit	„	22	10	0
§Ferro Chrome, Specially Refined, broken in small pieces for Crucible Steelwork. Quantities of 1 ton or over. Basis 60% Ch. Guar. max. 2% Carbon, scale 11/0 per unit	„	34	5	0
Guar. max. 1% Carbon, scale 12/6 per unit	„	36	10	0
§Guar. max. 0·7% Carbon, scale 15/– per unit	„	39	2	6
‡Manganese Metal 97–98% Mn.	lb.	0	1	4
‡Metallic Chromium	„	0	2	5
§ Ferro-Vanadium 25–50%	„	0	12	8
§ Spiegel, 18–20%	ton	7	10	0
Ferro Silicon—				
Basis 10%, scale 3/– per unit	ton	6	5	0
20/30% basis 25%, scale 3/6 per unit	„	8	2	6
45/50% basis 45%, scale 5/– per unit	„	11	17	6
70/80% basis 75%, scale 7/– per unit	„	18	10	0
90/95% basis 90%, scale 10/– per unit	„	28	17	6
§ Silico Manganese 65/75% Mn., basis 65% Mn.	„	13	15	0
§ Ferro - Carbon Titanium, 15/18% Ti	lb.	0	0	4½
Ferro Phosphorus, 20–25%	ton	15	18	0
§ Ferro-Molybdenum, Molyte	lb.	0	5	6
§ Calcium Molybdate	„	0	5	4

FUELS.

Foundry Coke—				
S. Wales	—		1	5 0
Scotland	—		1	8 0
Durham	1 1 0	to	1	5 0
Furnace Coke—				
Scotland	—		1	5 0
S. Wales	—		1	0 0
Durham	—		0	17 6

GUN METAL.

*Admiralty Gunmetal Ingots (88 : 10 : 2)	£53	10	0
*Commercial Ingots	41	0	0
*Gunmetal Bars, Tank brand, 1 in. dia. and upwards	lb.	0	0 9
*Cored Bars	„	0	0 11

LEAD.

Soft Foreign	£11	4	0
English	12	15	0

MANUFACTURED IRON.

Scotland—				
Crown Bars, Best	£10	5	0	
N.E. Coast—				
Rivets	10	15	0	
Best Bars	10	5	0	
Common Bars	9	5	0	
Lancashire—				
Crown Bars	9	12	6	
Hoops £10 10 0	to	12	0	0
Midlands—				
Crown Bars	9	12	6	
Marked Bars	12	0	0	
Unmarked Bars from	7	5	0	
Nut and Bolt Bars £7 10 0	to	8	0	0
Gas Strip	10	12	6	
S. Yorks—				
Best Bars	10	15	0	
Hoops £10 10 0	to	12	0	0

PHOSPHOR BRONZE.

*Bars, "Tank" brand, 1 in. dia. and upwards—Solid	lb.		9d.
*Cored Bars	„		11d.
†Strip	„		10d.
†Sheet to 10 W.G.	„		10½d.
†Wire	„		11¾d.
†Rods	„		10¾d.
†Tubes	„		1/4
†Castings	„		1/1½

†10% Phos. Cop. £30 above B.S.
†15% Phos. Cop. £35 above B.S.
†Phos. Tin (5%) £30 above English Ingots.

PIG IRON.

Scotland—			
Hematite M/Nos.	£3	11	0
Foundry No. 1	3	12	6
„ No. 3	3	10	0
N.E. Coast—			
Hematite No. 1	3	8	0
Foundry No. 1	3	10	0
„ No. 3	3	7	6
„ No. 4	3	6	6
Silicon Iron	3	10	0
Forge	3	6	6
Midlands—			
N. Staffs Forge No. 4	3	7	0
„ Foundry No. 3	3	11	0
Northants—			
Foundry No. 1	3	10	6
Forge No. 4	3	2	6
Foundry No. 3	3	7	6
Derbyshire Forge	3	6	0
„ Foundry No. 1	3	14	0
„ Foundry No. 3	3	11	0
West Coast Hematite	3	7	0
East „ „	3	8	0

SWEDISH CHARCOAL IRON AND STEEL.

Kr. per English ton @ 19·40 to £1 approximately.

Pig Iron Kr. 99
Billets Kr. 240-290 £13 10 0–£16 0 0
Wire Rods Kr. 280-320 £15 15 0–£17 12 6
Rolled Bars (dead soft) Kr. 190-210 £10 12 6–£11 11 0
Rolled Charcoal Iron Bars Kr. 290 16 0 0
All per English ton. f.o.b. Gothenburg.

SCRAP METAL.

Copper Clean	£25	0	0
„ Brazier	22	0	0
„ Wire		—	
Brass	18	0	0
Gun Metal	23	10	0
Zinc	9	0	0
Aluminium Cuttings	69	0	0
Lead	10	0	0
Heavy Steel—			
S. Wales	2	14	0
Scotland	2	10	0
Cleveland	2	10	0
Cast Iron—			
Midlands	2	7	6
S. Wales	2	7	0
Cleveland	2	12	0
Steel Turnings—			
Cleveland	1	17	6
Midlands	1	13	0
Cast Iron Borings—			
Cleveland	1	7	6
Scotland	2	0	0

SPELTER.

G.O.B. Official		—	
Hard	£11	0	0
English	14	2	0
India	13	0	0
Re-melted	14	0	0

STEEL.

Ship, Bridge, and Tank Plates Scotland	£8	15	0
North-East Coast	8	15	0
Midlands	8	17	6
Boiler Plates (Land), Scotland	8	10	0
„ „ (Marine) „		—	
„ „ (Land), N.E. Coast	8	10	0
„ „ (Marine) „	8	17	6
Angles, Scotland	8	7	6
„ North-East Coast	8	7	6
„ Midlands	8	7	6
Joists	8	15	0
Heavy Rails	8	10	0
Fishplates	12	10	0
Light Rails £8 10 0	to	8	15 0
Sheffield—			
Siemens Acid Billets	9	2	6
Hard Basic £6 17 6	to	7	2 6
Medium Basic £6 12 6	and	7	0 0
Soft Basic	5	10	0
Hoops £9 10 0	to	9	15 0
Manchester Hoops £9 0 0	to	10	0 0
Scotland, Sheets 24 B.G.	10	10	0

HIGH SPEED TOOL STEEL.

Finished Bars 14% Tungsten	lb.	2/–
Finished Bars 18% Tungsten	„	2/9
Extras		
Round and Squares, ¼ in. to ½ in.	„	3d.
Under ½ in. to ⅛ in.	„	1/–
Round and Squares 3 in.	„	4d.
Flats under 1 in. × ⅛ in.	„	3d.
„ „ ½ in. × ¼ in.	„	1/–

TIN.

Standard Cash	£231	0	0
English	231	0	0
Australian	230	17	0
Eastern	229	15	0
Tin Plates I.C. 20 × 14 box	17/3 to 7/6		

ZINC.

English Sheets	£23	5	0
Rods	27	10	0
Battery Plates		—	
Boiler Plates		—	

* McKechnie Brothers, Ltd., quoted July 13. † C. Clifford & Son, Ltd., quoted July 13. ‡ Murex Limited, quoted July 13.

Subject to Market fluctuations. Buyers are advised to send inquiries for current prices.

Prices quoted July 13, ex warehouse.